Further Assessment of Air Quality in Crieff

Perth & Kinross Council

Report for Perth & Kinross Council

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Executive summary

In this Further Assessment, concentrations of NO_2 and PM_{10} have been assessed in the Crieff AQMA in Perthshire. A combination of available monitoring data and atmospheric dispersion modelling using ADMS-Roads were used to conduct the study. The study used recently acquired traffic and meteorological data for Crieff to assess a baseline year of 2012.

The study has confirmed the findings of the previous Detailed Assessment, namely that there are exceedences of the annual mean NO_2 objective and annual mean PM_{10} objective where relevant exposure exists. The contour plots showing the modelled spatial variation in pollutant concentrations prepared for this study indicate that the current AQMA boundaries include all relevant sources and do not require revocation or amendments at this time.

Within the Crieff AQMA, the dispersion modelling results indicate that up to 70 residential properties within the AQMA were exposed to exceedences of the annual mean NO_2 and PM_{10} objectives during 2012 , equating to an exposed population of approximately 153 people.

It is estimated that emission reductions of Road NOx in the Crieff AQMA of up to 22% are required in order to achieve compliance with the annual mean NO_2 objective at all locations of relevant exposure. For compliance with the annual mean PM_{10} objective, it is estimated that a reduction in the Road contribution of PM_{10} of up to 46% is required.

The source apportionment exercise indicates that the proportion of emissions from queuing traffic is higher at the western end of West High Street than at other locations. Traffic surveys indicate that traffic appears to queue regularly throughout the day at this location with longer queues occurring during peak periods; this may be when vehicles are waiting to turn right onto Comrie Street.

The source apportionment also indicated that the highest proportion of NOx emissions at all receptors is from HGV's and Cars; and that NOx and PM_{10} emissions from buses are relatively low when compared to other vehicle types.

Three mitigation scenarios have been modelled as follows:

1. Reduce emissions by increasing the average vehicle speed through sections of the AQMA; achieved by implementing parking improvements.
2. Change priorities at the junction of West Street and Comrie Street where traffic turning right has been observed to queue while waiting for eastbound traffic to pass.
3. A decrease in the number of HGV traffic passing through the AQMA

The modelling results for the three mitigation scenarios indicated that each option will provide a reduction in both NOx and PM_{10} emissions. The predicted reduction in NO_2 concentrations were much greater than the predicted reduction in PM_{10} concentrations for all scenarios tested.

The modelling results indicate that compliance with the NO_2 annual mean objective may be achievable by implementing the measures modelled in this assessment. It is likely that a combination of measures will be required to reduce annual mean PM_{10} concentrations sufficiently to be compliant with the Scottish objective.

The monitoring and dispersion modelling carried out to support this Further Assessment indicates that exceedences of the NO_2 and PM_{10} annual mean objectives are still occurring within the Crieff AQMA. The boundary of the AQMA is therefore still appropriate and does not require to be revoked or amended at this time.

Perth & Kinross Council should continue with development of an Air Quality Action Plan for the Crieff AQMA and continue to monitor concentrations of PM_{10} and NO_2 in the area.

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1 Introduction

Ricardo-AEA has been commissioned by Perth & Kinross Council to conduct a Further Assessment of air quality in Crieff. This introductory section of the report outlines the purpose and scope of the assessment; and provides background information regarding the air quality review and assessment work completed to date at this location.

1.1 Policy Background

The Environment Act 1995 placed a responsibility on UK Government to prepare an Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland. The most recent version of the strategy (2007) sets out the current UK framework for air quality management and includes a number of air quality objectives for specific pollutants.

The 1995 Act also requires that Local Authorities “Review and Assess” air quality in their areas following a prescribed timetable. The Review and Assessment process is intended to locate and spatially define areas where the AQS objectives are not being met. In such instances the Local Authority is required to declare an Air Quality Management Area (AQMA), carry out a Further Assessment of Air Quality, and develop an Air Quality Action Plan (AQAP) which should include measures to improve air quality so that the objectives may be achieved in the future. The timetables and methodologies for carrying out Review and Assessment studies are prescribed in Defra’s Technical Guidance - LAQM.TG(09).

Table 1 lists the objectives relevant to this assessment that are included in the Air Quality Regulations 2000 and (Amendment) Regulations 2002 for the purposes of Local Air Quality Management (LAQM).

Table 1: NO_2 and PM_{10} Objectives included in the Air Quality Regulations and subsequent Amendments for the purpose of Local Air Quality Management

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Nitrogen dioxide	200 $\mu g.m^{-3}$ not to be exceeded more than 18 times a year	1 hour mean	31.12.2005
	40 $\mu g.m^{-3}$	Annual mean	31.12.2005
Particles (PM_{10}) (gravimetric) All authorities	50 $\mu g.m^{-3}$ not to be exceeded more than 35 times a year	24 hour mean	31.12.2004
	40 $\mu g.m^{-3}$	Annual mean	31.12.2004
Authorities in Scotland only[b]	50 $\mu g.m^{-3}$ not to be exceeded more than 7 times a year	24 hour mean	31.12.2010
	18 $\mu g.m^{-3}$	annual mean	31.12.2010

1.2 Purpose of the Further Assessment

This study is a Further Assessment, which aims to assess the magnitude and spatial extent of any exceedances of the annual mean air quality objectives for NO_2 and PM_{10} within the Air Quality Management Area (AQMA) that was declared at High Street in Crieff in February 2014. If exceedances are found, the study aims to confirm if the boundary of the existing AQMA is appropriate and will seek to apportion the main sources of pollutants so that action planning interventions may be appropriately targeted. When appropriate, action planning scenarios are also modelled to gauge how successful they might be should they be pursued by the Council.

1.3 Locations where the Air Quality Objectives apply

When carrying out the review and assessment of air quality it is only necessary to focus on areas where the public are likely to be regularly present and are likely be exposed over the averaging period of the objective. Table 2 summarises examples of where air quality objectives for NO_2 and PM_{10} should and should not apply.

Table 2: Examples of where the NO_2 Air Quality Objectives should and should not apply

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
Annual mean	NO_2, PM_{10}	All locations where members of the public might be regularly exposed. Building façades of residential properties, schools, hospitals, care homes etc.	Building facades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties. Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term
1-hour mean/24 hour mean	NO_2/PM_{10}	All locations where the annual mean and 24-hour mean objectives apply. Kerbside sites (e.g. pavements of busy shopping streets). Those parts of car parks and railway stations etc. which are not fully enclosed. Any outdoor locations to which the public might reasonably be expected to have access.	Kerbside sites where the public would not be expected to have regular access.

1.4 Overview of the approach taken

The general approach taken to this further assessment was to:

- Collect and interpret data from previous review and assessment reports.
- Collect and analyse the latest available traffic data, air quality monitoring data and background pollutant concentrations for use in the model.
- Confirm the findings of the Detailed Assessment and establish if the AQS objectives are still likely to be exceeded.
- Model NO_2 and PM_{10} concentrations and produce contour plots of the modelled pollutant concentrations to verify if the boundary of the existing AQMA is valid.

- Apportion the main sources of NO_2 and PM_{10}
- Recommend whether Perth & Kinross Council should retain/amend or revoke their AQMA
- Model action planning scenarios

The methodologies outlined in Technical Guidance LAQM.TG(09) were used throughout this further assessment.

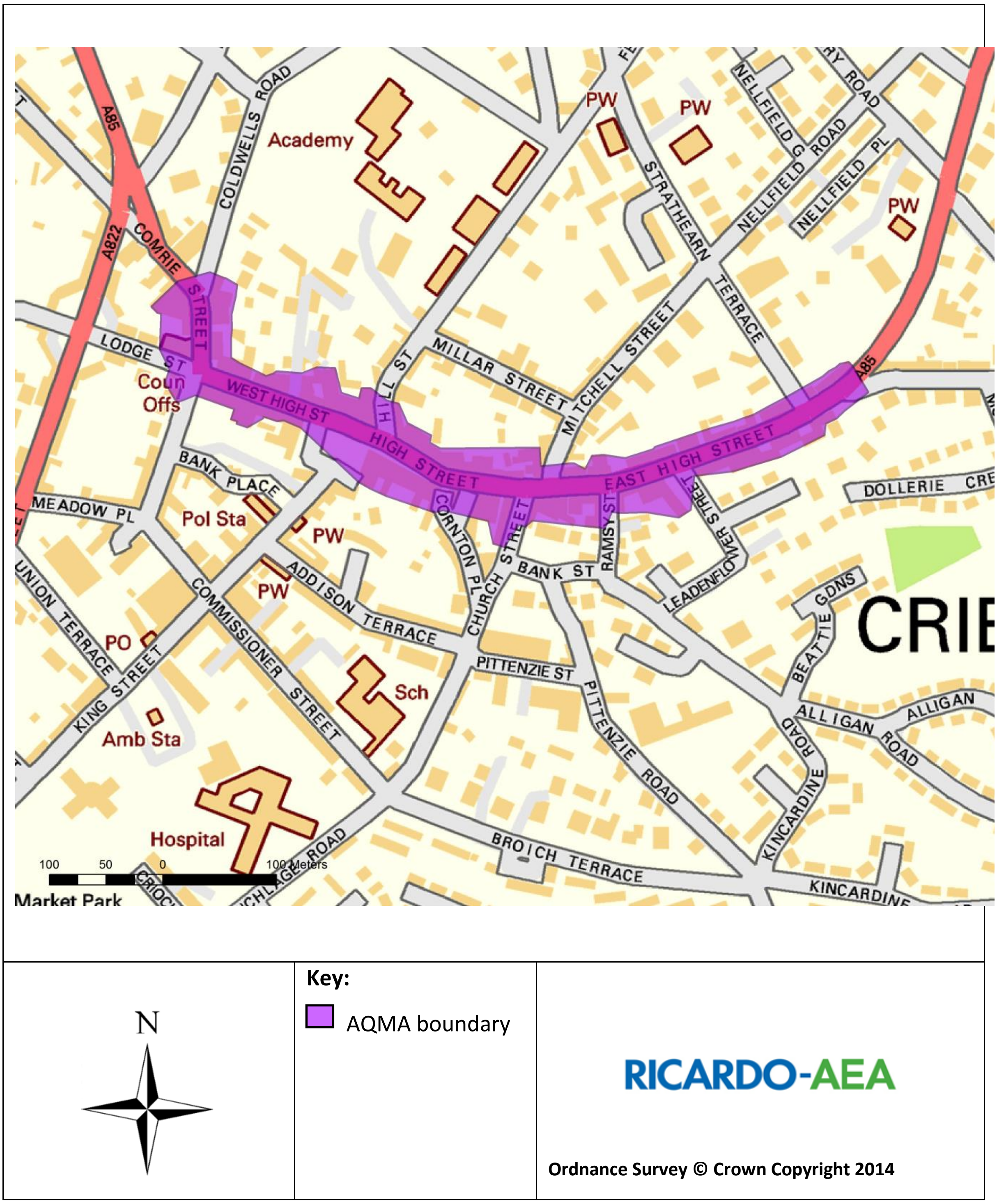
1.5 Study area and AQMA Location

The market town of Crieff is located approximately 15 miles west of Perth along the A85 trunk road. The town is a popular tourist area and has a resident population of approximately 6000. Crieff is the second largest town in Perthshire.

This further assessment is concerned with emissions from road traffic travelling along the sections of the A85 that pass through the centre of the town; including West High Street, High Street and East High Street. These streets have many three storey buildings on both sides of the road with commercial properties on the ground floor and residential properties on the first floor and above. At some locations, the relatively high sided building when compared to the street width creates narrow street canyons within the AQMA; this type of topography is known to limit dispersion of air pollution.

The Crieff AQMA was declared in February 2014. The AQMA is for exceedances of the annual mean objective for both NO_2 and PM_{10}. The boundary of the AQMA is presented on Figure 1.

Figure 1: Crieff AQMA



2 Information used to support this assessment

2.1 Maps

Ordnance Survey based GIS data of the model domain and a road centreline GIS dataset were used in the assessment. This enabled accurate road widths and the distance of the housing to the kerb to be determined in ArcMap.

2.2 Road traffic data

2.2.1 Average flow, speed and fleet split

Traffic data for the assessment was available from both local surveys commissioned by Perth & Kinross Council; and from the freely available Transport Scotland/DfT national traffic count datasets.

Annual average daily traffic (AADT) flows and vehicle fleet split data for the A85 was accessed from the national traffic datasets.

The local traffic surveys conducted in May 2013 provided detailed information on various different elements. The data used for the Further Assessment included observed vehicle queue lengths, typical stop times at the pedestrian crossings, and journey times through different sections of the town which allowed estimates of average speeds to be calculated.

Some notable observations relating to the traffic survey and count data were:

- The average journey time surveys indicated that average vehicle speeds through Crieff are relatively low in comparison with the speed limit. Which may mean that, if possible, increasing speed and hence flow, is a potential option for reducing NOx and PM_{10} emissions within the AQMA.
- HGVs account for approximately 5% of the average daily traffic flow through the town
- The AADT flow along the A85 of 5931 is relatively low; dispersion of traffic emissions is however restricted by the high sided fairly narrow streets along High Street.

Appendix 2 summarises all of the traffic flow data used, data sources and any assumptions made.

It should be noted that traffic patterns in urban locations are complex and it is not possible to fully represent these in atmospheric dispersion models. By attempting to describe these complex traffic patterns using quite simple metrics (AADT, average speed and vehicle split composition) a degree of uncertainty is inherent within the modelling.

2.2.2 Congestion

During congested periods average vehicle speeds reduce when compared to the daily average; the combination of slower average vehicle speeds and more vehicles lead to higher pollutant emissions during peak hours; it's therefore important to account for this when modelling vehicle emissions to estimate pollutant concentrations.

Traffic can become slow moving and congested at certain locations in Crieff during peak times. Vehicle queue observations were made during a one-day traffic survey conducted in May 2013.

Queuing was observed at the western end of West High Street; westbound traffic appears to queue regularly throughout the day at this location with longer queues occurring during peak periods, this may be a result of vehicles waiting to turn right onto Comrie Street.

Surveys of the typical stop times at the two main pedestrian crossings on the High Street were used to calculate an indicative average time per hour that vehicles queue at these traffic lights.

A method of modelling queuing traffic using ADMS-Roads proposed by model developers CERC has been used to represent periodic traffic congestion. The method assumes that the vehicles are travelling at the lowest speed that can be modelled using ADMS-Roads (5 km/hr), with an average vehicle length of 4m, and are positioned close to each other during congested periods. The annual average hourly traffic (AAHT) flow is calculated by dividing the speed of the vehicles by the average vehicle length, which gives a representative AAHT of 1250 vehicles per hour during congested periods. A time–varying file is then used in the model to turn the congested road sections on for the relevant fraction of each hour of the day when congestion is known to occur.

2.2.3 Emission factors

At the time of modelling, the latest version of the Emissions Factors Toolkit[1] (EFT V5.2c Jan 2013) release) was used in this assessment to calculate pollutant emissions factors for each road link modelled. The calculated emission factors were then imported in to the ADMS-Roads model.

Parameters such as traffic volume, speed and fleet composition are entered into the EfT, and an emissions factor in grams of NOx/kilometre/second is generated for input into the dispersion model. In the latest version of the EfT, NOx emissions factors previously based on DFT/TRL functions have been replaced by factors from COPERT 4 v8.1. These emissions factors were published in May 2011 through the European Environment Agency and are widely used for the purpose of calculating emissions from road traffic in Europe.

The latest version of the EfT also includes addition of road abrasion emission factors for particulate matter; and changes to composition of the vehicle fleet in terms of the proportion of vehicle km travelled by each Euro standard, technology mix, vehicle size and vehicle category.

Vehicle emission projections are based largely on the assumption that emissions from the fleet will reduce as newer vehicles are introduced. Any inaccuracy in the emissions factors contained in the EfT will be unavoidably carried forward into this modelling assessment.

2.2.4 Gradients

Hills with gradients may slow traffic significantly. As vehicles start to climb the hill, the power demand from the engine will increase, hence vehicle emissions will increase. However for vehicles going downhill, the opposite occurs and emissions decrease.

A method to derive the change in vehicles emissions attributable to a vehicle ascending or descending a hill is described in the LAQM technical guidance document TG(09)(Section A2.19). The guidance recommends that for passenger cars and light diesel vehicles (LDVs) normal speed related emission factors should be used, taking into account that the average speed on the hill section may differ to that on the flatter sections.

For heavy diesel vehicles (HDVs) there are larger and more significant changes in emissions when ascending and descending a hill. Equations have been derived to calculate how gradients change emission rates; the equations are based on relationships developed from fitting speed related emission factors in the EMEP Corinair Emissions guidebook for gradients of +2%, +4% and +6%.

[1] http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft

The gradient of various road sections throughout the study area was calculated using ground level altitudes extracted from digital elevation model (DEM) data; the percentage gradient between each height sample point was calculated using the measured distance between each point and the difference in altitude. For road sections where the gradient was greater than 2.5% a revised emission factor was calculated using the gradient adjustment equations provided in TG(09). The section of Comrie Road close to the junction with West High Street has a relatively steep gradient of approximately 4.8%; adjustments were calculated and applied to vehicle emission rates at this location.

2.3 Meteorological data

Hourly sequential meteorological data (wind speed, direction etc.) for 2012 from the Strathallen meteorological measurement site was obtained from a third party supplier and used for the modelling assessment. The meteorological measurement site is located approximately 8 km to the south east of the study area and has good data quality for the period of interest.

Meteorological measurements are subject to their own uncertainty which will unavoidably carry forward into this assessment.

2.4 Background concentrations

Background NOx concentrations for a dispersion modelling study can be derived from either local monitoring data conducted at a background site or from the Scottish LAQM background maps[2].

There were no urban background measurements available for use in the study therefore the mapped background NOx and PM_{10} concentrations were used in the study. A CSV file containing concentrations across the Perth & Kinross Council area was obtained and the background NOx and PM_{10} concentrations for the appropriate grid square extracted. The source contributions of background pollutant concentrations attributable to road traffic on the primary A roads within the study area have been subtracted from the total background to avoid double counting emissions from the roads.

The mapped annual mean NOx background concentration for the relevant grid square during 2012 was 7.8 $\mu g.m^{-3}$ and for annual mean PM_{10} was 11.5 $\mu g.m^{-3}$. It should be noted that the background maps are the outputs of a national scale dispersion model provided at a 1km x 1km resolution and are therefore subject to a degree of uncertainty.

[2] SAQD (2013) http://www.scottishairquality.co.uk/maps

3 Ambient monitoring

Perth & Kinross Council currently measures NO_2 and PM_{10} concentrations at one continuous analyser in Crieff; and also measures NO_2 concentrations at eight diffusion tube sites within the study area. A map showing the location of the monitoring sites is presented in Figure 2.

Details of the monitoring sites and the annual mean concentrations measured during 2012 are presented for NO_2 in Table 3 and PM_{10} in Table 4. These data are consistent with those presented in Perth & Kinross Council's 2013 Progress Report. All diffusion tube results have been bias adjusted using a local co-location factor of 0.99 from another of the Council's automatic sites. Full details of bias adjustment factors applied to the diffusion tube results and QA/QC procedures are presented in Appendix 4.

The diffusion tube sites are typically located at a few metres height, so although not located exactly at locations of relevant exposure where the closest residential properties are at first floor height; the measured annual mean NO_2 concentrations are broadly reflective of exposure in the streets with canyon like topography that are present in many parts of the model domain.

Annual mean NO_2 concentrations in excess of the 40 $\mu g.m^{-3}$ objective were measured during 2012 at three of the diffusion tubes on East and West High Street; all of which are locations where the buildings form street canyons. The annual mean PM_{10} measurement at the automatic analyser was less than the 18 $\mu g.m^{-3}$ Scottish objective during 2012. The automatic analyser is however located in James square, which is fairly open with good air circulation when compared with the nearby locations where there are street canyons. Comparison of the measured NO_2 annual mean at the automatic analyser in comparison with the nearby diffusion tube measurements within the street canyons indicates that this is the case; there may therefore be PM_{10} concentrations in excess of the Scottish annual mean objective occurring within sections of the study area with canyon like topography.

Table 3: NO_2 measurements 2012 - comparison with annual mean objective

Site	Type	OS Grid Ref.		Relevant exposure Y/N with distance (m)	Data Capture 2012 (%)	NO_2 Annual mean 2012 ($\mu g.m^{-3}$)
		Easting	Northing			
Crieff automatic monitor	R	286361	721618	Y (19.5 m)	80 %	23
7 West High St	R	286334	721638	Y (10 m)	83 %	**52**
39, High St	R	286505	721555	Y (18 m)	92 %	35
62, High St	R	286551	721563	Y (1 m)	92 %	31
9 East High St	R	286577	721554	Y (5 m)	92 %	**41**
19 West High Street	R	286301	721651	Y (0 m)	92 %	**42**
43 High Street	R	286538	721551	Y (0 m)	92 %	32
10/12 West High Street	R	286313	721635	Y (0.5 m)	92 %	39
9 Comrie Street	R	286270	721699	Y (0 m)	92 %	21
1 Lodge Street	R	286204	721688	Y (0 m)	92 %	26

Exceedances of the annual mean objective are highlighted in **bold**
R – Roadside monitoring location, 1-5m from the kerb of a busy road

Table 4: PM_{10} measurements 2012 – comparison with annual mean objective

Site	Type	OS Grid Ref.		Relevant exposure Y/N with distance (m)	Data Capture 2012 (%)	PM_{10} Annual mean 2012 ($\mu g.m^{-3}$)
		Easting	Northing			
Crieff automatic monitor	R	286361	721618	Y (19.5 m)	88.1 %	16
Exceedances of the annual mean objective are highlighted in **bold**						
R – Roadside monitoring location, 1-5m from the kerb of a busy road						

Figure 2: Crieff air quality monitoring locations

Legend:

Monitoring location

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Contains Ordnance Survey data © Crown copyright and database right 2014

4 Modelling

4.1 Modelling methodology

Annual mean concentrations of NO_2 for the base year of 2012 have been modelled within the study area using the atmospheric dispersion model ADMS Roads (version 3.2).

The model was verified by comparing the modelled predictions of road NOx with local monitoring results. The available measurements (described in Section 3 above) were used to verify the annual mean road NOx model predictions. Following initial comparison of the modelled concentrations with the available monitoring data, refinements were made to the model input to achieve the best possible agreement with the monitoring results. Further information on model verification is provided in Section 4.1.3 and Appendix 1.

A surface roughness of 1 m was used in the modelling to represent the urban conditions in the model domain. A limit for the Monin-Obukhov length of 10 m was applied to represent a small town.

The source-oriented grid option was used in ADMS-Roads; this option provides finer resolution of predicted pollutant concentrations along the roadside, with a wider grid spaced at approximately 6m being used to represent concentrations further away from the road. The grid height was set at 1.5m to represent human exposure at head height. The predicted concentrations were interpolated to derive values between the grid points using the Spatial Analyst tool in the GIS software ArcMap 10. This allows contours showing the predicted spatial variation of pollutant concentrations to be produced and added to the digital base mapping.

It should be noted that any dispersion modelling study has a degree of uncertainty associated with it; all reasonable steps have been taken to reduce this where possible.

Queuing traffic was treated in the model using the methodology described in Section 2.2.2 above as provided by the model developers. Queuing was assigned to specific road sections based on local knowledge and observations of typical congestion patterns. A time varying emissions file was used in the model to account for the daily variations in queuing traffic.

4.1.1 Treatment of modelled NOx road contribution

It is necessary to convert the modelled NOx concentrations to NO_2 for comparison with the relevant objectives. The Defra NOx/NO_2 model[3] was used to calculate NO_2 concentrations from the NOx concentrations predicted by ADMS-Roads. The model requires input of the background NOx, the modelled road contribution and accounts for the proportion of NOx released as primary NO_2. For the Perth & Kinross Council area in 2012 with the “All UK Traffic” option specified in the model, the NOx/NO_2 model estimates that 22.9% of NOx is released as primary NO_2.

4.1.2 Validation of ADMS Roads

Validation of the model is the process by which the model outputs are tested against monitoring results at a range of locations and the model is judged to be suitable for use in specific applications; this is usually conducted by the model developer.

CERC have carried out extensive validation of ADMS applications by comparing modelled results with standard field, laboratory and numerical data sets, participating in EU workshops on short range dispersion models, comparing data between UK M4 and M25 motorway field monitoring data, carrying out inter-comparison studies alongside other modelling solutions such as DMRB and CALINE4, and

[3] Defra (2010) NOx to NO_2 conversion spreadsheet; Available at http://laqm1.defra.gov.uk/review/tools/monitoring/calculator.php

carrying out comparison studies with monitoring data collected in cities throughout the UK using the extensive number of studies carried out on behalf of local authorities and Defra.

4.1.3 Verification of the baseline model

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. This helps to identify how the model is performing in comparison with local measurements. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. LAQM.TG(09) recommends making the adjustment to the road contribution of the pollutant only and not the background concentration these are combined with.

The approach outlined in Example 2 of LAQM.TG(09) has been used in this case.

The modelled NOx concentrations were verified using the available measurements from the roadside automatic and diffusion tube monitoring sites in the study area.

Following various refinements to the model input; the modelled Road NOx contribution required adjustment by an average factor of 2.4359 to bring the predicted NO_2 concentrations within close agreement of those results obtained from the monitoring data. This factor was applied to all Road NOx concentrations predicted by the model; the adjusted total NO_2 concentrations were then calculated using the Defra NOx/NO_2 calculator.

After the NOx/NO_2 model was run no further adjustments were made to the data. Model agreement for the NO_2 monitoring data after adjustment is presented in Table 5.

Table 5: Modelled vs. measured annual mean NO_2 concentrations

Site	NO_2 annual mean concentration (µg.m^{-3})	
	Measured	Modelled
Crieff Auto	23.0	23.0
19 West High Street	42.0	40.5
10/12 West High St	39.0	38.9
9 Comrie Street	21.0	23.1
39 High Street	35.0	35.5
43 High Street	32.0	31.9
62 High Street	31.0	31.7
	RMSE =	**1.03**

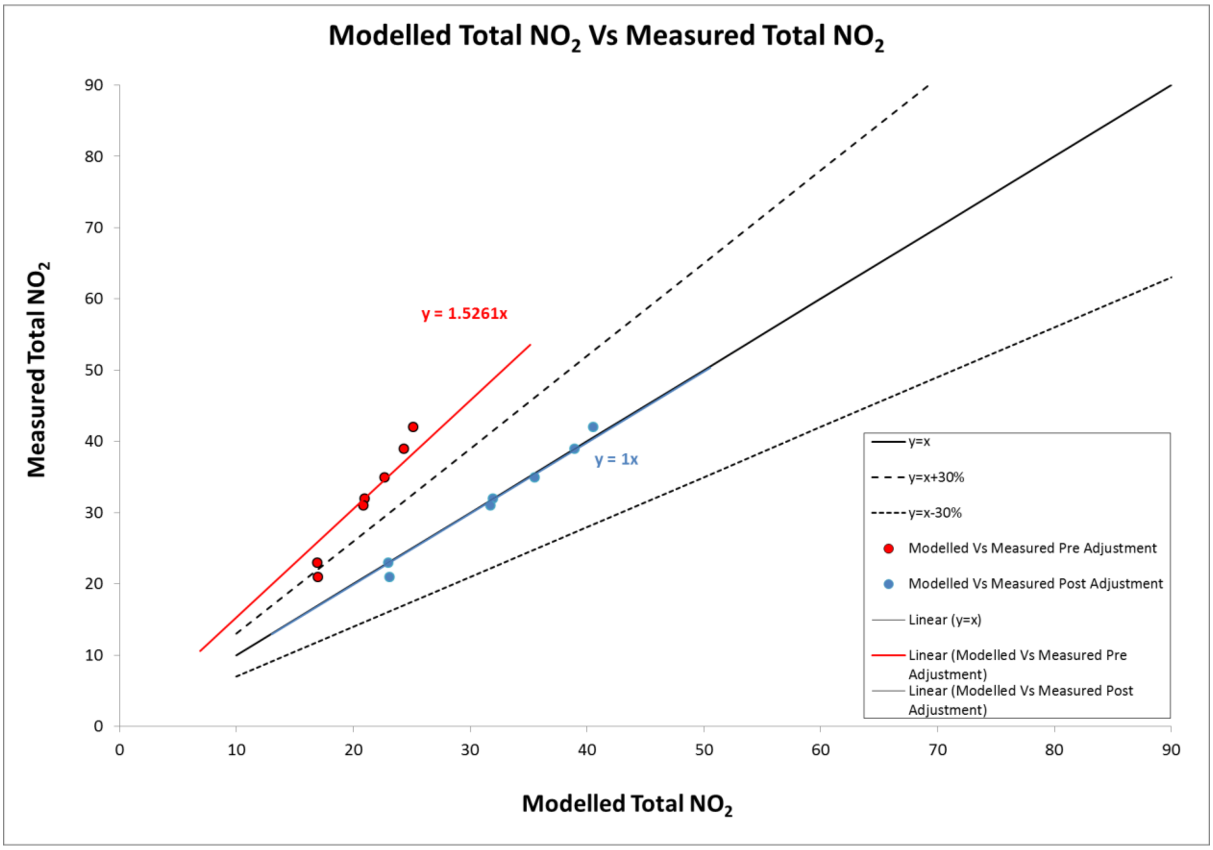
Model uncertainty can be estimated by calculating the root mean square error (RMSE). In this case the calculated RMSE was just greater than 1 µg.m^{-3} after adjustment which is within the suggested value (10% of the objective being assessed) in LAQM.TG(09). The model has therefore been assessed to perform sufficiently well for use within this assessment.

Verifying modelling data with diffusion tube monitoring data will always be subject to uncertainty due to the inherent limitations in such monitoring data (even data from continuous analysers has notable uncertainty). The model results should be considered in this context.

Based on a comparison of the monitored road contribution of PM_{10}, and the modelled road contribution of PM_{10} at the automatic monitor site; the model was found to be under-predicting PM_{10} concentrations and was corrected using a factor of 4.86.

It is not possible to estimate the RMSE in the PM_{10} model as only one monitoring site is available for comparison. However, the low RMSE based on NO_2 agreement indicates that the predicted PM_{10} values are reasonable given the common source of both pollutants. Further information on the verification process including the linear regression analysis is provided in Appendix 3- the plot of the result is provided in Figure 3.

Figure 3: Linear regression analysis of modelled vs. monitored NO_2 annual mean



4.2 Base year modelling results

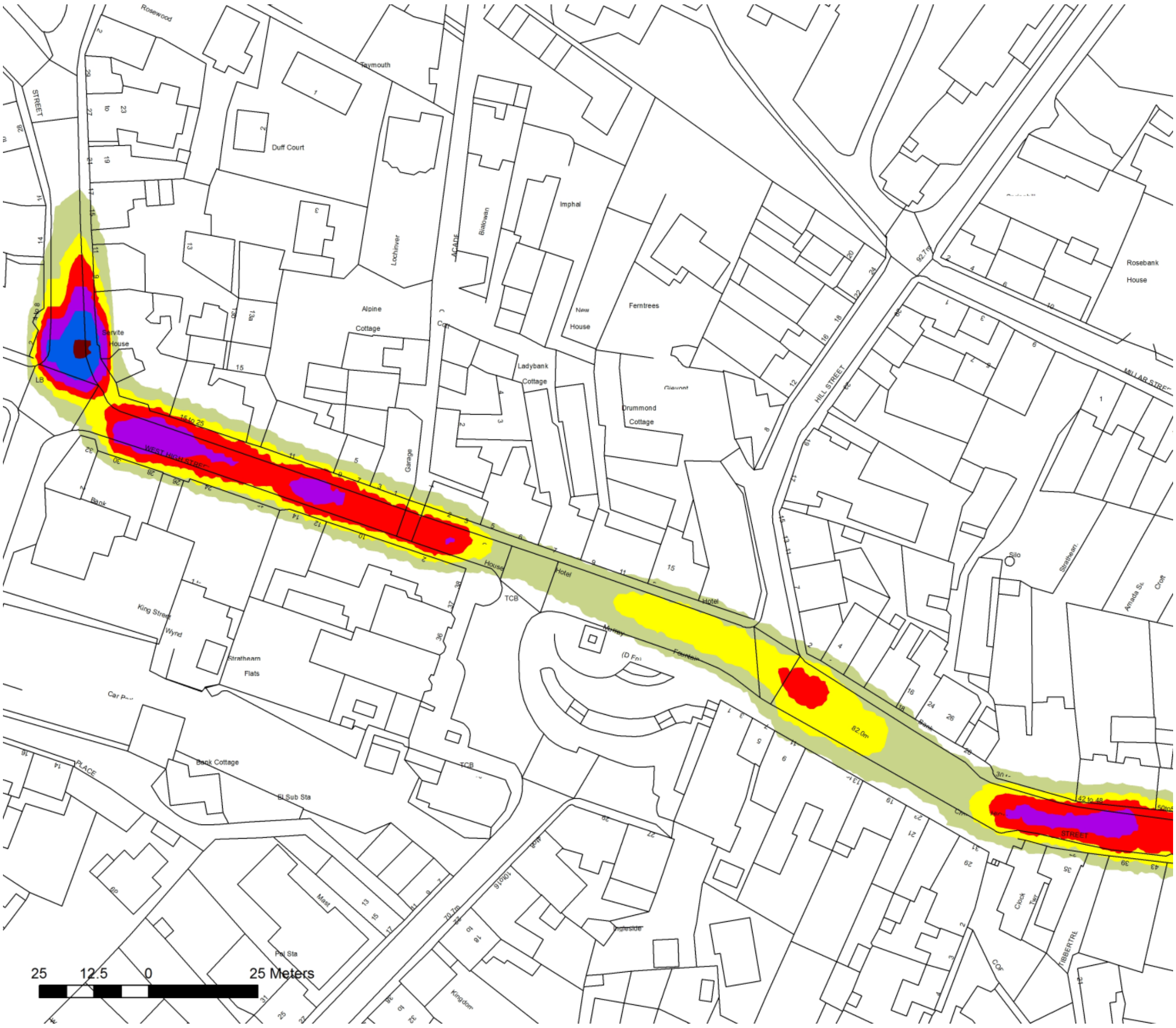
Annual mean NO_2 and PM_{10} concentrations were predicted at a selection of receptor locations within the study area to identify the worst case locations at which the source apportionment should be conducted. All receptors were located at the facade of residential buildings in the model domain where relevant exposure exists by the roads sources being modelled. The receptors were modelled at both 1.5m height to represent ground level exposure; and at 4 m to represent exposure at first floor height above commercial properties where residential properties may be present.

Pollutant concentrations have also been predicted across a grid of points to allow pollutant contour plots showing the spatial variation in pollutant concentrations across the study area to be created. Contour plots showing the spatial variation in predicted annual mean NO_2 and PM_{10} concentrations at ground level across the study area presented in Figure 4 to Figure 6 for NO_2 and Figure 7 to Figure 9 for PM_{10}. The plots indicate that the highest concentrations and exceedances of each respective annual mean objective are occurring at the locations where traffic congestion was observed during the traffic surveys; at the pedestrian crossings within the street canyon topography in High Street and at the junction of West High Street and Comrie Road. The conclusions from the baseline model are broadly similar to the Detailed Assessment and do not show any areas of exceedance out-with the existing AQMA boundary.

The extent of the current AQMA boundary overlaid with the predicted NO_2 and PM_{10} annual mean contour are presented in Figure 10 and Figure 11 respectively. The locations where exceedances are predicted at locations where relevant exposure exists are within the existing AQMA boundary. This confirms that, based on the monitoring conducted in 2012 and the subsequent modelling, that the existing AQMA boundary is appropriate.

The dispersion modelling results indicate that up to 70 residential properties within the AQMA were exposed to exceedences of the annual mean NO_2 and PM_{10} objectives during 2012.

Figure 4: Predicted NO_2 annual mean concentrations at 1.5m height: West High St & Comrie St



Legend:

NO_2 annual mean concentration ($\mu g.m^{-3}$)

- < 30
- 30 - 36
- 36 - 40
- 40 - 44
- 44 - 50
- 50 - 60
- 60 - 63.7

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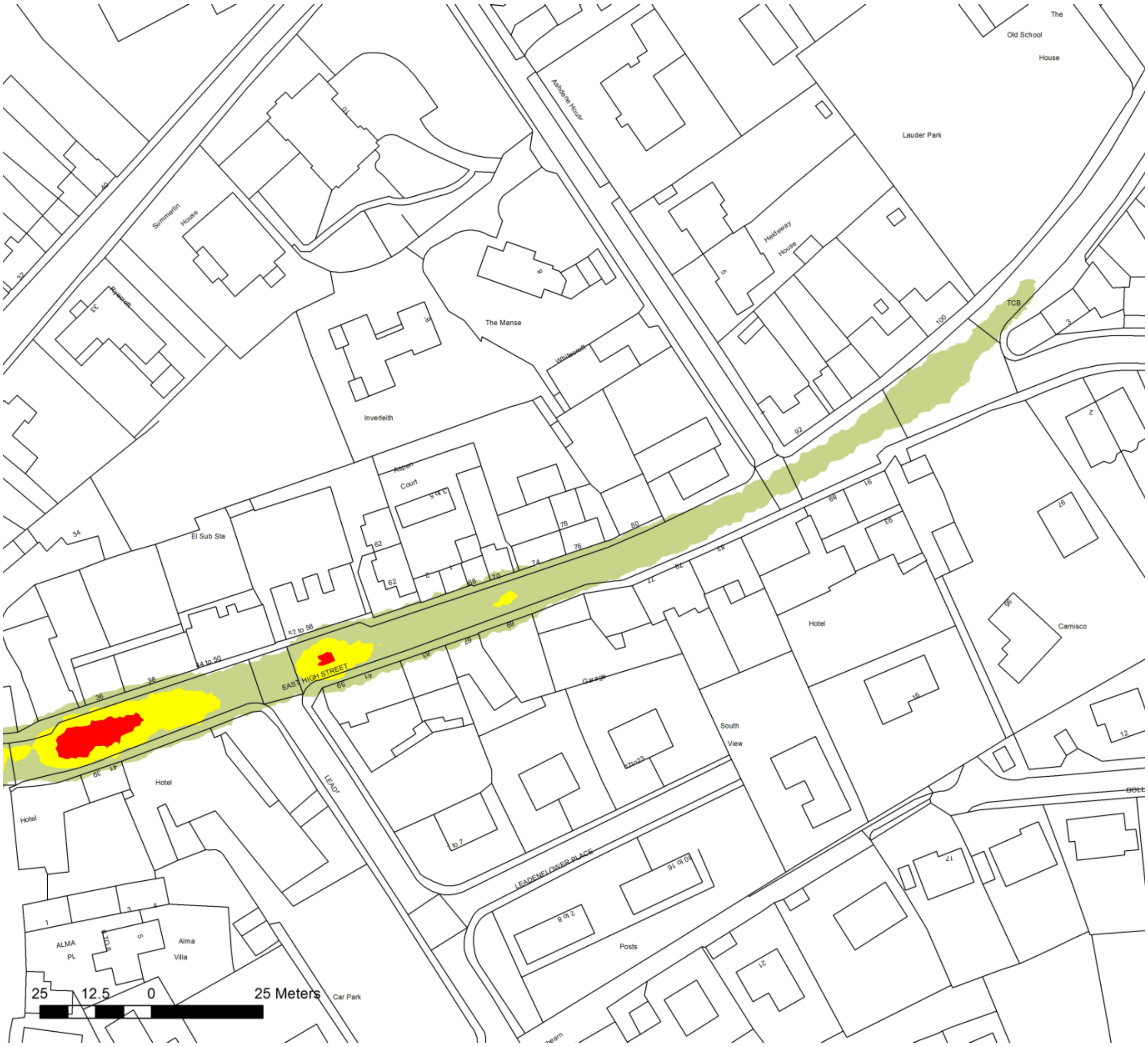
Figure 5: Predicted NO_2 annual mean concentrations at 1.5m height – East High Street



Legend:

NO_2 annual mean concentration ($\mu g.m^{-3}$)

- < 30
- 30 - 36
- 36 - 40
- 40 - 44
- 44 - 50
- 50 - 60
- 60 - 63.7

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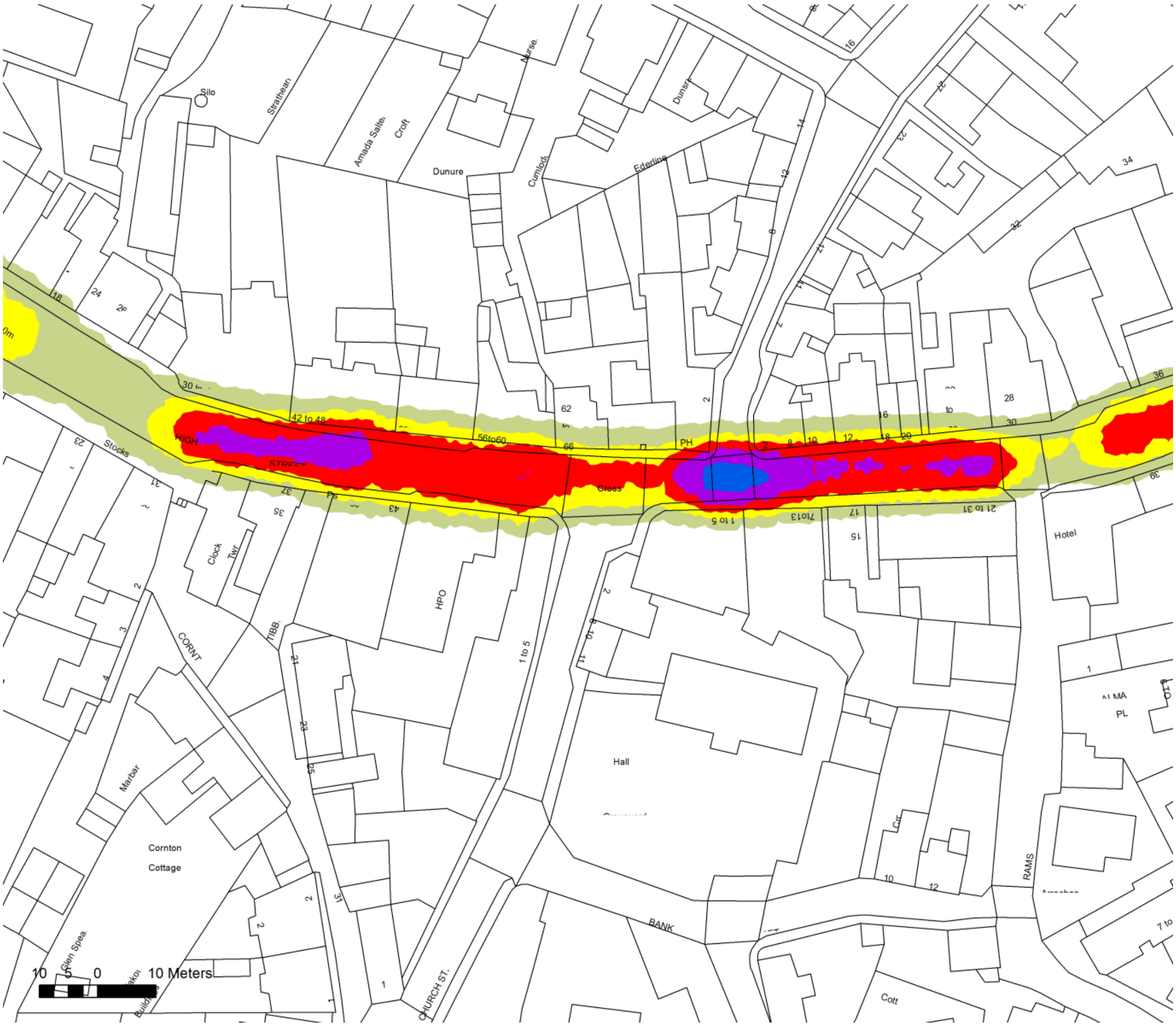
Figure 6: Predicted NO_2 annual mean concentrations at 1.5m height – High Street



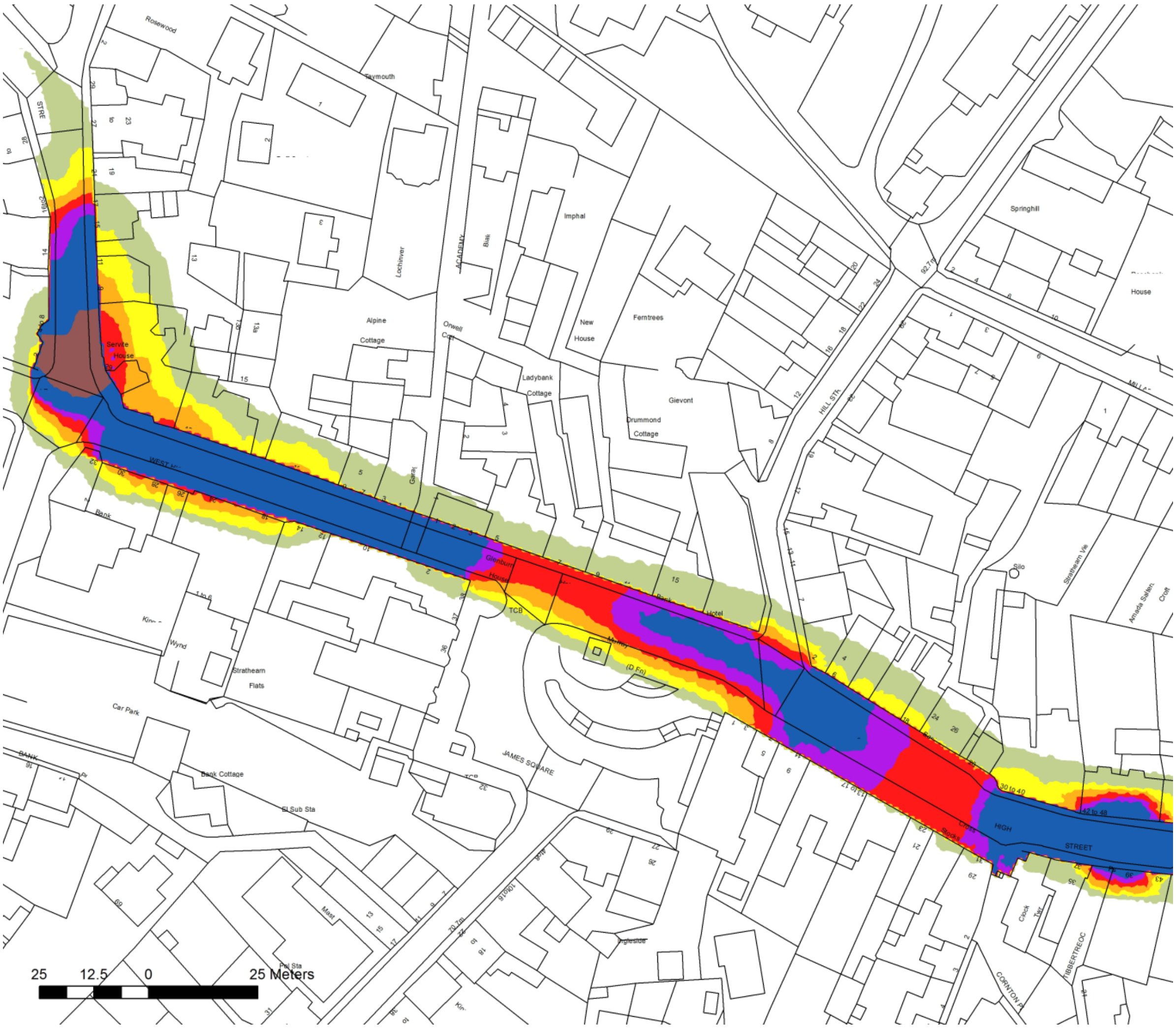
N

Legend:

NO_2 annual mean concentration ($\mu g.m^{-3}$)

- < 30
- 30 - 36
- 36 - 40
- 40 - 44
- 44 - 50
- 50 - 60
- 60 - 63.7

Figure 7: Predicted PM_{10} annual mean concentrations at 1.5m height: West High St & Comrie St



Legend:

PM_{10} annual mean concentration ($\mu g.m^{-3}$)

- < 15
- 15 - 16
- 16 - 17
- 17 - 18
- 18 - 19
- 19 - 20
- 20 - 25
- 25 - 32.4

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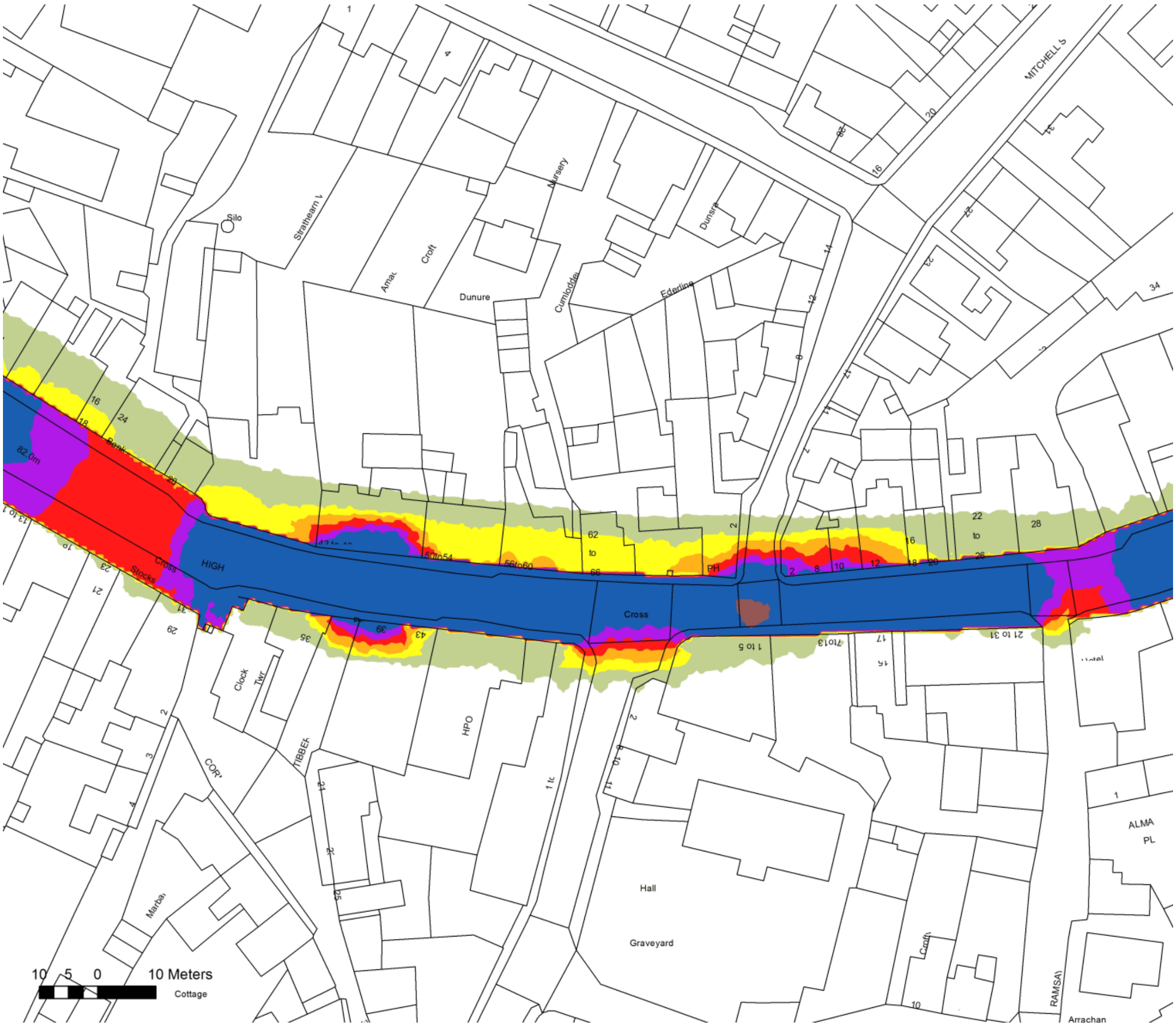
Figure 8: Predicted PM_{10} annual mean concentrations at 1.5m height – High Street



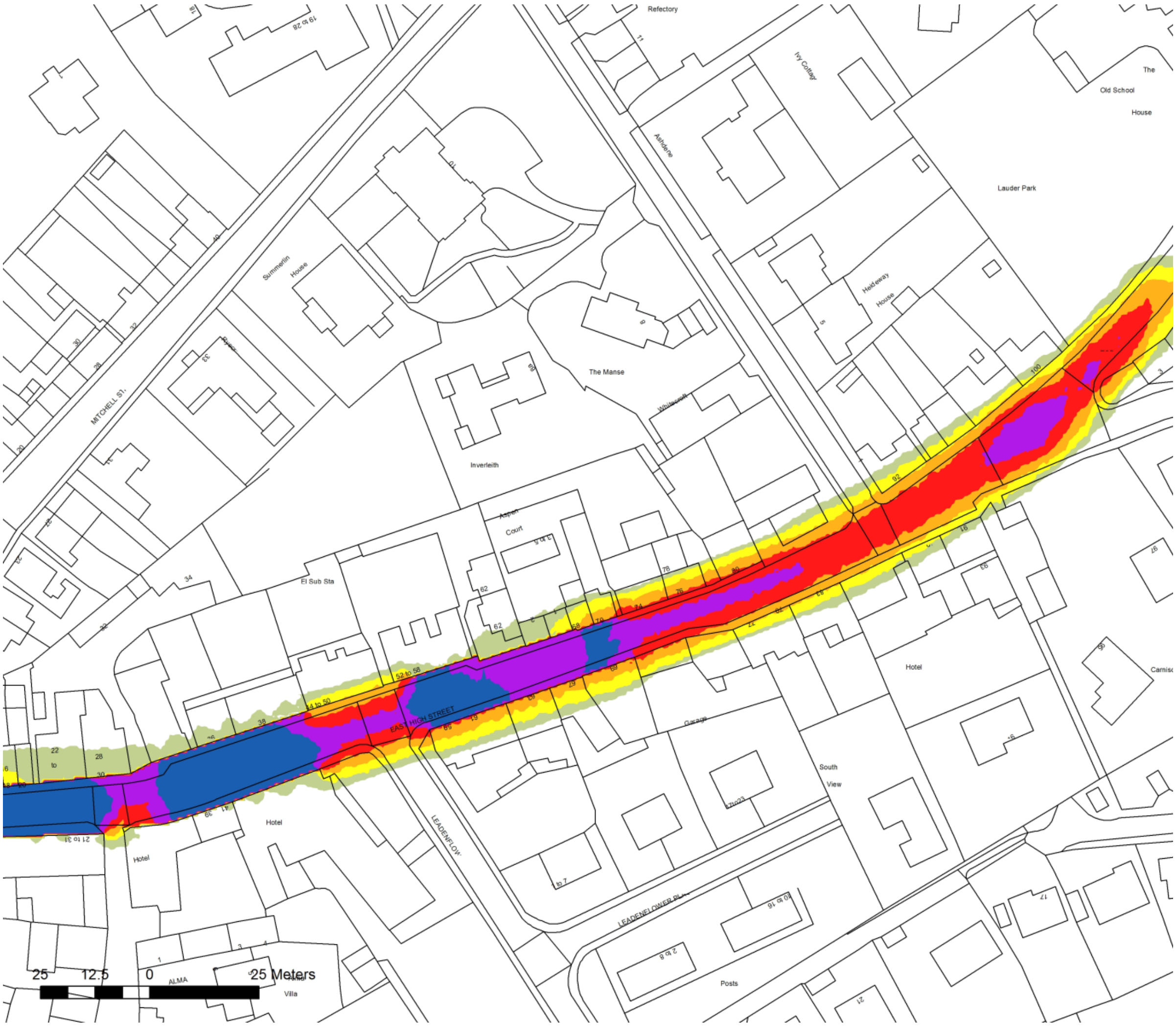
Legend:

PM_{10} annual mean concentration ($\mu g.m^{-3}$)

- < 15
- 15 - 16
- 16 - 17
- 17 - 18
- 18 - 19
- 19 - 20
- 20 - 25
- 25 - 32.4

RICARDO-AEA

Figure 9: Predicted PM_{10} annual mean concentrations at 1.5m height – East High Street



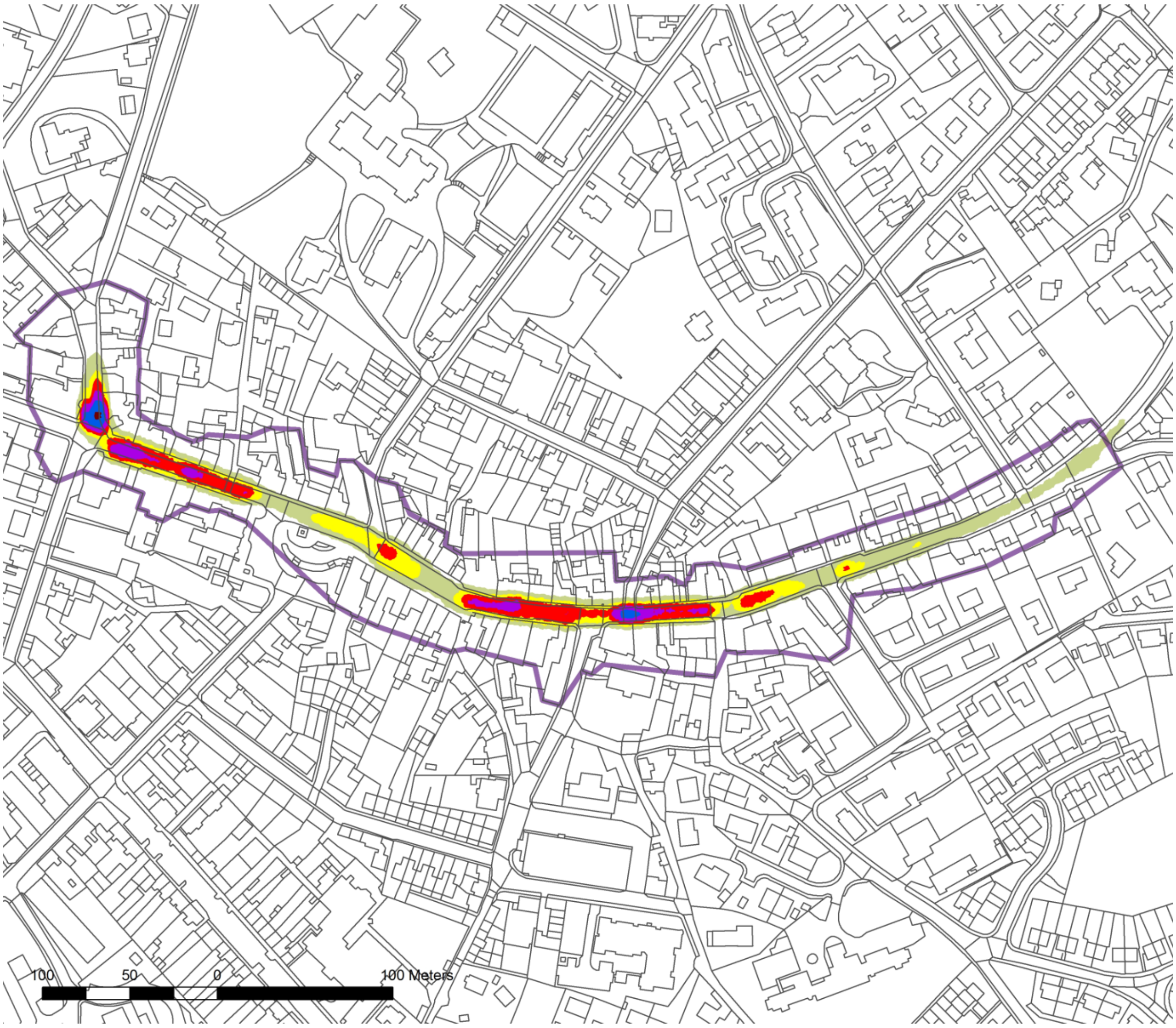
Legend:

PM_{10} annual mean concentration ($\mu g.m^{-3}$)

- < 15
- 15 - 16
- 16 - 17
- 17 - 18
- 18 - 19
- 19 - 20
- 20 - 25
- 25 - 32.4

RICARDO-AEA

Figure 10: Crieff AQMA boundary compared with NO_2 annual mean concentrations at 1.5m height



Legend:

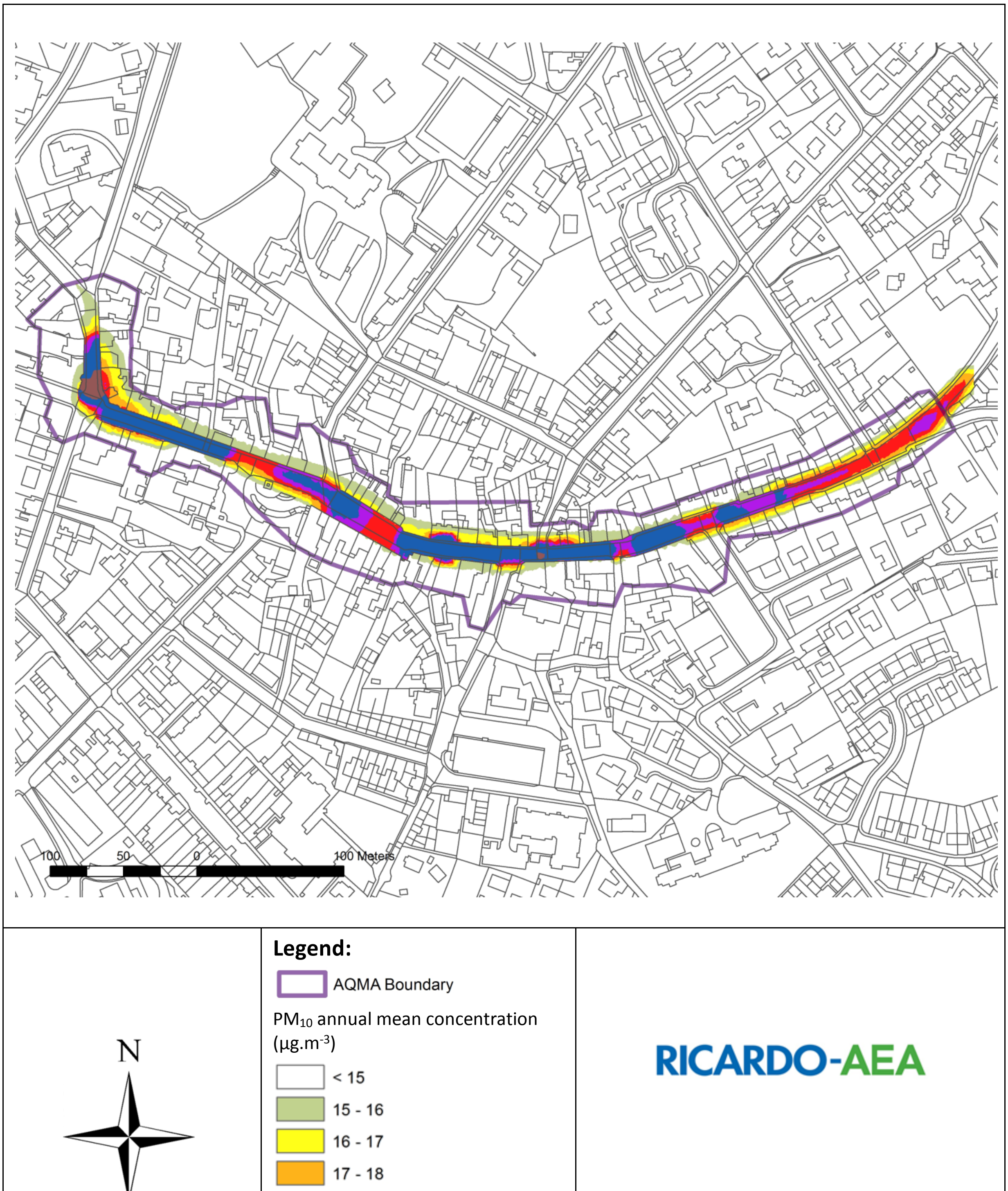
AQMA Boundary

NO_2 annual mean concentration ($\mu g.m^{-3}$)

- < 30
- 30 - 36
- 36 - 40
- 40 - 44
- 44 - 50
- 50 - 60
- 60 - 63.7

RICARDO-AEA

Figure 11: Crieff AQMA boundary compared with PM_{10} annual mean concentrations at 1.5m height



5 Source Apportionment

Source apportionment is the process whereby the contribution of different pollutant sources to ambient concentrations are quantified. This aims to allow the Local Authority's action plan to target specific sources when attempting to reduce pollutant concentrations in the AQMA.

The source apportionment for the Crieff AQMA assessment should:

- Confirm that exceedances of the NO_2 and PM_{10} objective are due to road traffic.
- Determine the extent to which different vehicle types are responsible for the emission contributions to NOx/NO_2 and PM_{10}.
- Quantify what proportion of total NOx and PM_{10} are due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedance, or, whether national measures would be a suitable approach to achieving the air quality objectives.

The 'Baseline' is the modelling of annual mean NOx and PM_{10} concentrations without any measures to reduce these concentrations by Perth & Kinross Council. In this case, the baseline is the modelling of emissions in 2012 as described in Section 4 above. To calculate the proportion of total NOx and PM_{10} concentrations attributable to various types of vehicles, the EfT was used within which emission sources were effectively switched on or off accordingly e.g. for calculating the contribution from HGVs all other sources were set to zero. This allowed derivation of new emission factors for the road segments which were then modelled in ADMS-Roads to obtain the contribution of each source to ambient NOx and PM_{10} concentrations at the worst-case specified receptor locations i.e. the locations where the highest concentrations were predicted.

The contributions from each of the following sources have been quantified:

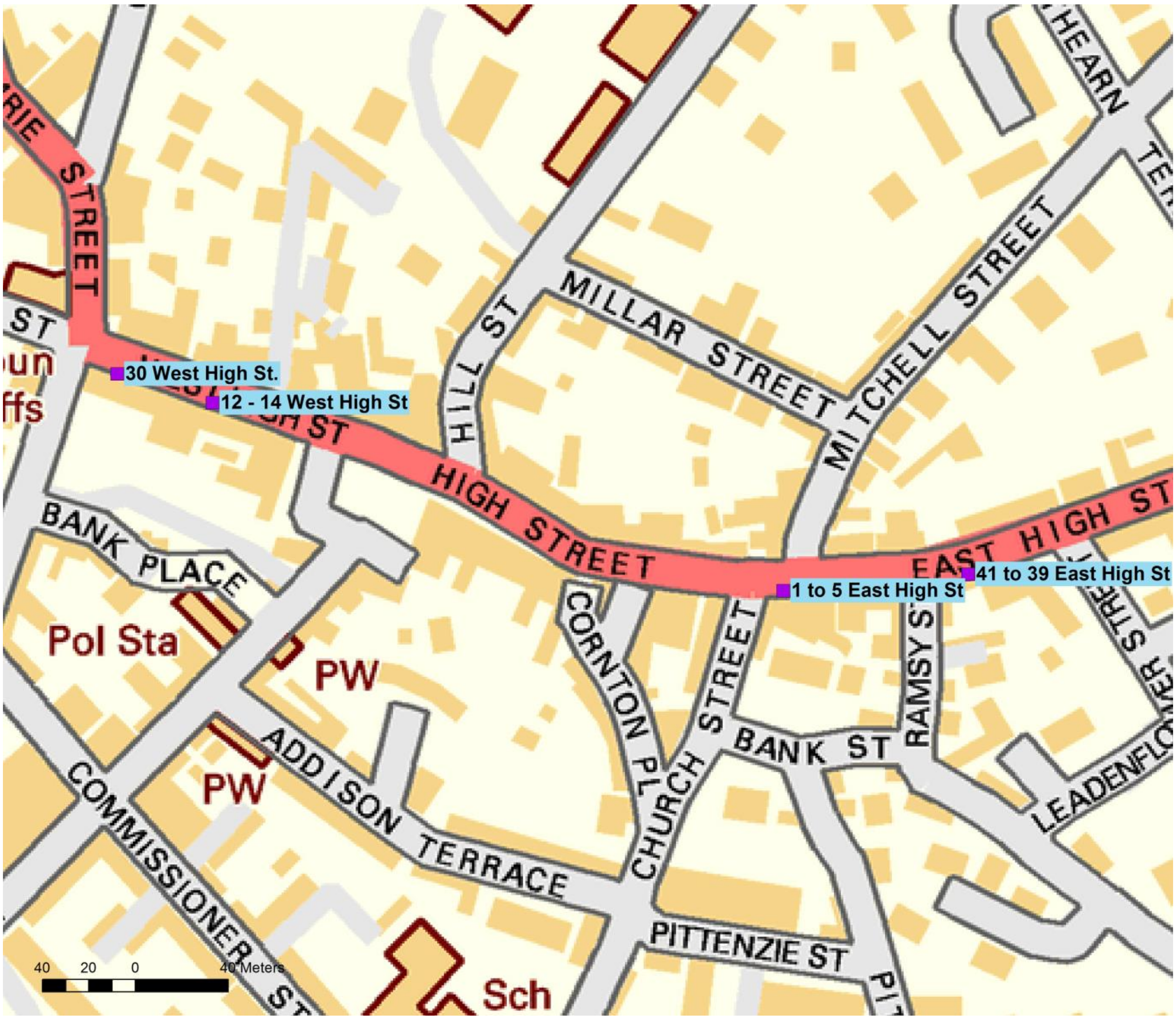
- Background
- Moving vehicles
- Queuing vehicles
- Cars
- Light Goods Vehicles
- Heavy Goods Vehicles
- Buses

Table 6 to Table 13 summarise the relevant NOx and PM_{10} contributions from the above sources at the worst-case receptor locations. A map showing the locations of the worst-case receptors is presented in Figure 12. The source apportionment results are presented visually using segmented bar charts for NOx and PM_{10} in Figure 13 to Figure 16.

Examination of the source apportionment results indicates that:

- The proportion of emissions from queuing traffic is higher at the western end of West High Street than at other locations. The traffic surveys indicate that traffic appears to queue regularly throughout the day at this location with longer queues occurring during peak periods; this may be when vehicles are waiting to turn right onto Comrie Street.
- The highest proportion of NOx emissions at all receptors are from HGVs and Cars.
- NOx and PM_{10} emissions from buses are relatively low when compared to other vehicle types.

Figure 12: Worst case receptor locations used for source apportionment



Legend:

Worst case receptor location

Table 6: NOx Source Apportionment - Moving and Queuing Vehicles (µg.m^{-3})

Receptor location	Contribution to annual mean NOx (µg.m^{-3})				
	Total NOx	Background	Road NOx	Moving traffic	Queuing Traffic
30 West High St (1st floor)	88.6	7.8	80.8	68.7	12.2
12 - 14 West High St (1st floor)	95.1	7.8	87.3	81.0	6.4
1 to 5 East High St (1st floor)	105.8	7.8	98.0	90.9	7.1
41 to 39 East High St (ground floor)	83.9	7.8	76.1	70.3	5.8

Table 7: NOx Source Apportionment - Moving and Queuing Vehicles (% of total NOx)

Receptor location	Contribution to annual mean NOx (%)				
	Total NOx	Background	Road NOx	Moving traffic	Queuing Traffic
30 West High St (1st floor)	100%	8.8%	91.2%	77.5%	13.7%
12 - 14 West High St (1st floor)	100%	8.2%	91.8%	85.1%	6.7%
1 to 5 East High St (1st floor)	100%	7.4%	92.6%	85.9%	6.7%
41 to 39 East High St (ground floor)	100%	9.3%	90.7%	83.8%	6.9%

Table 8: NOx source apportionment – Contribution by vehicle type (µg.m^{-3}) (excludes motorcycles)

Receptor location	Contribution to annual mean NOx (µg.m^{-3})						
	Total NOx	Background	Road NOx	Cars	HGV	Buses	LGV
30 West High St (1st floor)	88.6	7.8	80.8	27.1	34.4	7.2	12.1
12 - 14 West High St (1st floor)	95.1	7.8	87.3	30.4	35.8	7.3	13.9
1 to 5 East High St (1st floor)	105.8	7.8	98.0	34.0	40.4	8.1	15.5
41 to 39 East High St (ground floor)	83.9	7.8	76.1	27.3	30.5	6.0	12.4

Table 9: NOx source apportionment – Contribution by vehicle type (% of total NOx)

Receptor location	Contribution to annual mean NOx (% contribution)						
	Total NOx	Background	Road NOx	Cars	HGV	Buses	LGV
30 West High St (1st floor)	100.0%	8.8%	91.2%	30.6%	38.8%	8.2%	13.7%
12 - 14 West High St (1st floor)	100.0%	8.2%	91.8%	32.0%	37.6%	7.6%	14.6%
1 to 5 East High St (1st floor)	100.0%	7.4%	92.6%	32.2%	38.2%	7.7%	14.6%
41 to 39 East High St (ground floor)	100.0%	9.3%	90.7%	32.5%	36.3%	7.1%	14.8%

Table 10: PM_{10} Source Apportionment - Moving and Queuing Vehicles ($\mu g.m^{-3}$)

Receptor location	Contribution to annual mean PM_{10} ($\mu g.m^{-3}$)				
	Total PM_{10}	Background	Road PM_{10}	Moving traffic	Queuing Traffic
30 West High St (1st floor)	21.3	11.9	9.4	7.5	1.9
12 - 14 West High St (1st floor)	22.1	11.9	10.2	9.9	0.3
1 to 5 East High St (1st floor)	23.3	11.9	11.4	11.0	0.4
41 to 39 East High St (ground floor)	21.2	11.9	9.3	9.2	0.1

Table 11: PM_{10} Source Apportionment - Moving and Queuing Vehicles (%)

Receptor location	Contribution to annual mean PM_{10} (%)				
	Total PM_{10}	Background	Road PM_{10}	Moving traffic	Queuing Traffic
30 West High St (1st floor)	100%	55.9%	44.1%	35.4%	8.7%
12 - 14 West High St (1st floor)	100%	53.9%	46.1%	44.8%	1.3%
1 to 5 East High St (1st floor)	100%	51.0%	49.0%	47.1%	1.9%
41 to 39 East High St (ground floor)	100%	56.1%	43.9%	43.5%	0.5%

Table 12: PM_{10} source apportionment – Contribution by vehicle type ($\mu g.m^{-3}$) (excludes motorcycles)

Receptor location	Contribution to annual mean PM_{10} ($\mu g.m^{-3}$)						
	Total PM_{10}	Background	Road PM_{10}	Cars	HGV	Buses	LGV
30 West High St (1st floor)	21.3	11.9	9.4	4.8	2.0	0.4	2.2
12 - 14 West High St (1st floor)	22.1	11.9	10.2	5.5	2.1	0.4	2.2
1 to 5 East High St (1st floor)	23.3	11.9	11.4	6.1	2.4	0.4	2.5
41 to 39 East High St (ground floor)	21.2	11.9	9.3	5.2	1.9	0.3	1.9

Table 13: PM_{10} source apportionment – Contribution by vehicle type (%)

Receptor location	Contribution to annual mean PM_{10} (% contribution)						
	Total PM_{10}	Background	Road PM_{10}	Cars	HGV	Buses	LGV
30 West High St (1st floor)	100%	55.9%	44.1%	22.4%	9.4%	1.8%	10.4%
12 - 14 West High St (1st floor)	100%	53.9%	46.1%	24.7%	9.7%	1.8%	9.9%
1 to 5 East High St (1st floor)	100%	51.0%	49.0%	26.3%	10.3%	1.8%	10.5%
41 to 39 East High St (ground floor)	100%	56.1%	43.9%	24.3%	9.0%	1.6%	9.1%

Figure 13: Crieff AQMA - NOx source apportionment (expressed in µg.m^{-3})

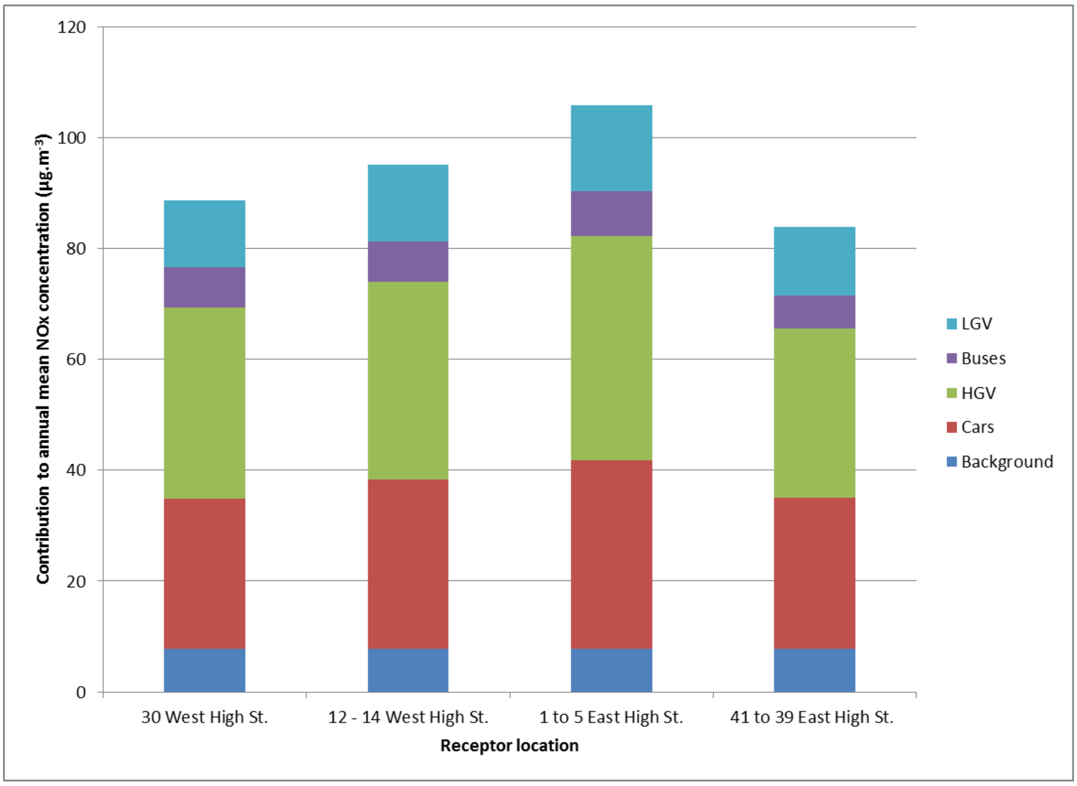


Figure 14: Crieff AQMA - NOx source apportionment (expressed as a percentage)

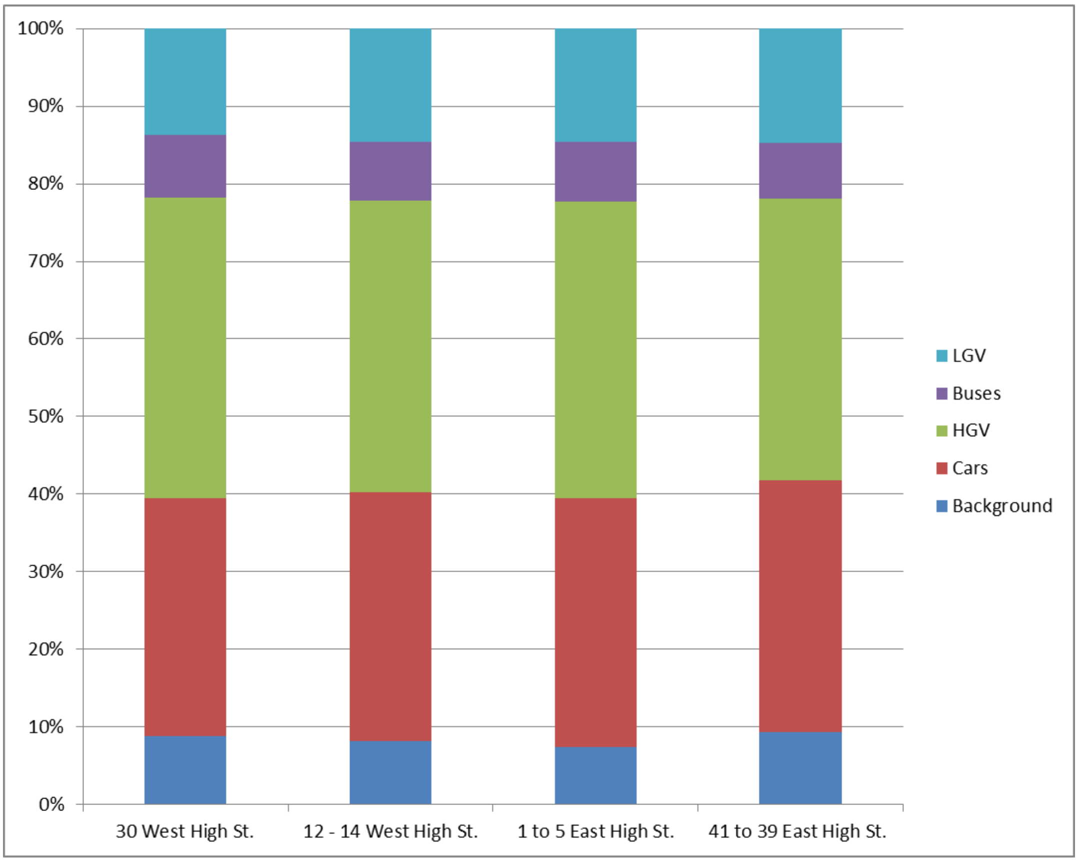


Figure 15: Crieff AQMA - PM_{10} source apportionment (expressed in $\mu g.m^{-3}$)

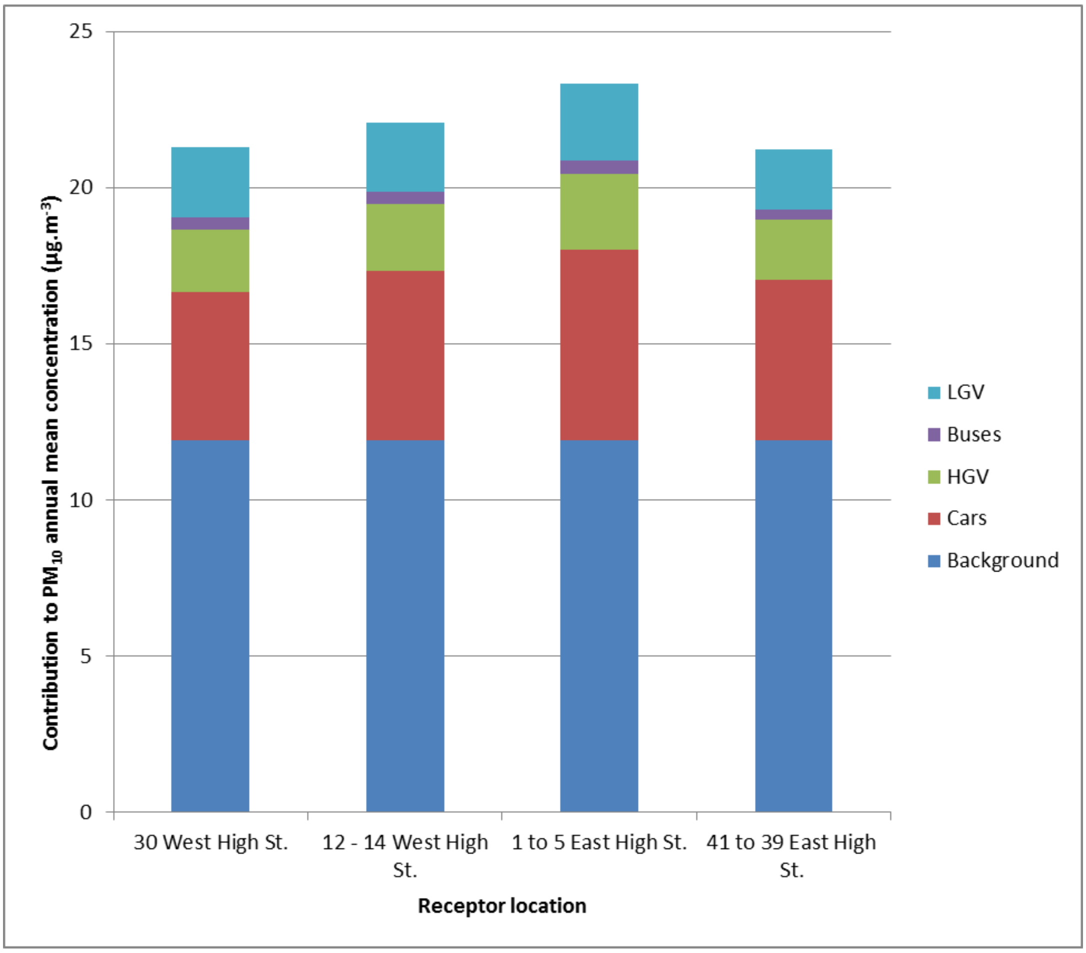
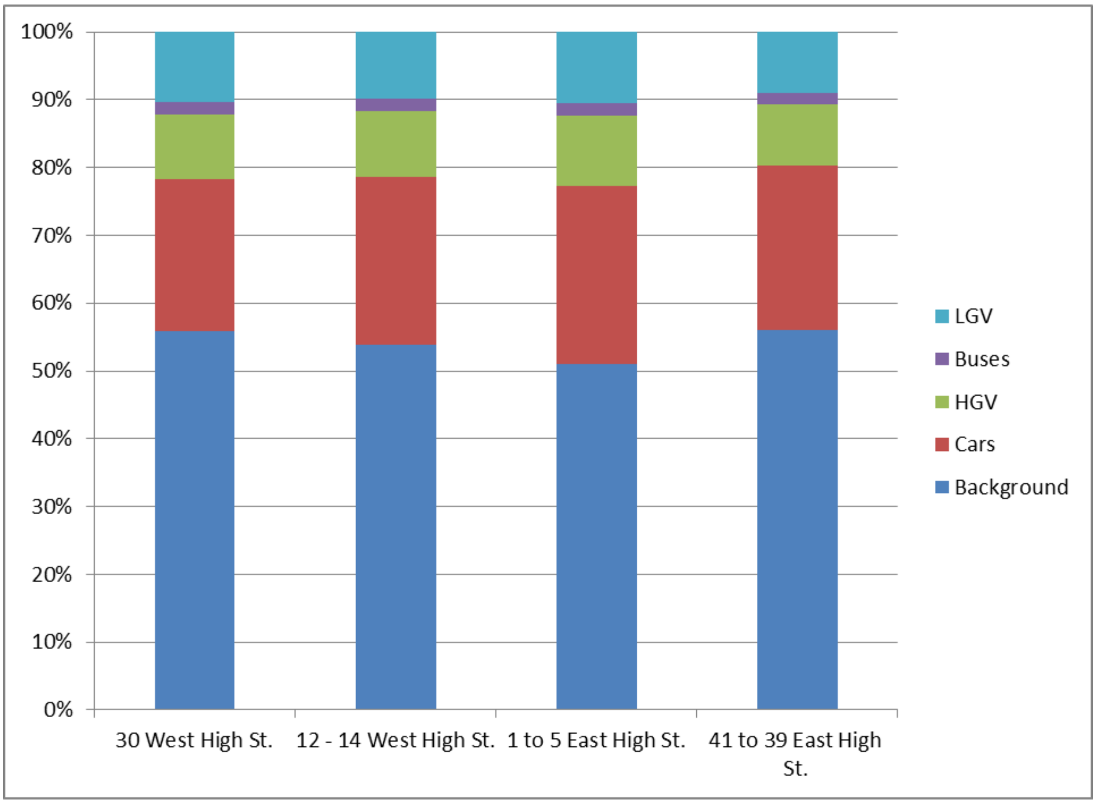


Figure 16: Crieff AQMA - PM_{10} source apportionment (expressed as a percentage)



6 Required reduction in ambient NOx concentrations

The required reduction in Road-NOx and PM_{10} concentrations to attain the objectives allows the Local Authority to judge the scale of the effort required to comply with each respective air quality objective.

For NO_2, the required reduction in road contribution to ambient concentrations should be expressed in terms of NOx as this is the primary emission and a non-linear relationship exists between NOx and NO_2 concentrations. The ambient concentrations of NOx required to achieve the annual mean objective for NO_2 at the locations of worst-case relevant exposure have been derived using the NOx/NO_2 calculator as described previously.

It should be noted that these data pertain to the ambient concentration reductions required to achieve the NO_2 annual mean objective of 40 $\mu g.m^{-3}$. The required reductions in Road NOx at each of the locations included in the source apportionment study are presented in Table 14. Note that at 39 to 41 East High Street the modelled NO_2 annual mean concentration is below the 40 $\mu g.m^{-3}$ objective, this receptor has been included for being in excess of the annual mean PM_{10} objective only.

Table 14: Required reduction in Road NOx concentrations to achieve NO_2 annual mean of 40 $\mu g.m^{-3}$

Receptor	Current Road-NO_x ($\mu g.m^{-3}$)	Required Road-NOx ($\mu g.m^{-3}$)	Road NO_x Reduction required (%)
30 West High St (1st floor)	80.8	76.2	6%
12 - 14 West High St (1st floor)	87.3	76.2	13%
1 to 5 East High St (1st floor)	98.0	76.2	22%

For PM_{10} the required reductions in the road contribution of PM_{10} at the worst case receptor locations are presented in Table 15.

Table 15: Required reduction in Road-PM_{10} concs. to achieve 18 $\mu g.m^{-3}$ annual mean objective.

Receptor	Current Road PM_{10} ($\mu g.m^{-3}$)	Required Road-PM_{10} ($\mu g.m^{-3}$)	Road PM_{10} Reduction required (%)
30 West High St (1st floor)	9.4	6.1	35%
12 - 14 West High St (1st floor)	10.2	6.1	40%
1 to 5 East High St (1st floor)	11.4	6.1	46%
41 to 39 East High St (ground floor)	9.3	6.1	34%

7 Mitigation Scenarios

Three test option scenarios have been modelled in order to assess the level of intervention that would be required to meet the NO_2 and PM_{10} objectives at all locations of relevant exposure. Each test option aims to represent a traffic management option that is potentially viable within the Crieff AQMA based on the local circumstances and conclusions of the source apportionment study.

The scenarios have been modelled in ADMS-Roads using the same methodology as described above but with updated traffic data to reflect the potential effect of each proposed traffic management option.

The effect on ambient concentrations of NO_2 and PM_{10} for each option has been modelled at the worst-case receptor locations used for the source apportionment study.

The test options modelled were:

1. Reduce emissions by increasing the average vehicle speed through sections of the AQMA; achieved by implementing parking improvements.

2. Change priorities at the junction of West Street and Comrie Street where traffic turning right has been observed to queue while waiting for eastbound traffic to pass.

3. A decrease in the number of HGV traffic passing through the AQMA

The predicted change in annual mean NO_2 and PM_{10} concentrations at each of the worst case receptors in the study in comparison with the 2012 baseline is presented for each scenario below.

7.1 Test Option 1 – Increase average speed via parking restrictions

This scenario investigates the potential reductions in NO_2 and PM_{10} annual mean concentrations that can be achieved by implementing roadside parking restrictions along the main road in Crieff.

The average journey time measurements conducted during the recent traffic survey indicated that average vehicle speeds through Crieff are fairly low. This may mean that, if possible, increasing speed and hence flow, is a potential option for reducing NOx and PM_{10} emissions within the AQMA. Slow moving traffic may be attributable to vehicles waiting to take parking spaces and the resulting delays while traffic behind waits as vehicles enter and leave roadside parking spaces.

To test what is potentially achievable by increasing average speed, five sub-scenarios have been tested to represent varying average speed changes up to the speed limit of 30 mph at locations where traffic can be free flowing.

For the baseline model, average speeds for three different sections of the A85 were calculated from the traffic survey data. Some reduction in average speeds was assumed in the baseline model at links approaching junctions/pedestrian crossing etc. but the overall average speed for the links in each section is roughly the same as calculated from the journey time surveys.

To calculate the resulting change in vehicle emissions for potential increases in average speed up to the speed limit, the minimum headroom in speed was calculated for each section i.e. 30mph minus the speed in the fastest road link within each section. E.g. a section with average link speeds ranging from 10 mph to 23 mph has headroom of 30 mph minus 23 mph = 7 mph.

As test options, link speeds were then increased using five incremental percentages of the headroom for each section. The results at the worst case receptors locations are presented for NO_2 in Table 16 and for PM_{10} in Table 17.

The modelling results indicate that both annual mean NO_2 and PM_{10} concentrations will decrease as average speeds increase towards the speed limit at different locations within the AQMA.

The predicted NO_2 annual mean is less than the 40 $\mu g.m^{-3}$ objective after a 20% of headroom increase in speed at all of the worst case receptor locations modelled; with the exception of 1 to 5 East High Street where an 80% headroom increase in speed is required before the predicted annual mean is within the 40 $\mu g.m^{-3}$ objective. At this location an 80% of headroom increase would represent achieving an average speed of approximately 28 mph.

Examination of the predicted annual mean PM_{10} concentrations at all of the receptors modelled indicate that smaller reductions will be achieved for PM_{10} and will not be sufficient to achieve compliance with the 18 $\mu g.m^{-3}$ Scottish annual mean objective at any of the worst case receptor locations.

Table 16: Scenario 1 – Increase average speed through AQMA – Predicted NO_2 annual mean concentrations at worst case receptors

Receptor	Minimum headroom to 30mph speed limit	2012 baseline NO_2 annual mean	NO_2 annual mean with percentage increase of minimum headroom to 30 mph speed limit				
			20% ($\mu g.m^{-3}$)	40% ($\mu g.m^{-3}$)	60% ($\mu g.m^{-3}$)	80% ($\mu g.m^{-3}$)	100% ($\mu g.m^{-3}$)
30 West High St (1st floor)	17.5 mph	**40.5**	37.4	34.9	33.0	31.5	30.2
12 - 14 West High St (1st floor)	17.5 mph	**42.3**	39.0	36.3	34.2	32.4	31.1
1 to 5 East High St (1st floor)	8.1 mph	**45.8**	**44.0**	**42.4**	**41.0**	39.7	38.5
41 to 39 East High St (ground floor)	8.1 mph	38.7	37.3	36.0	34.9	33.9	32.9

Table 17: Scenario 1 – Increase average speed through AQMA – Predicted PM_{10} annual mean concentrations at worst case receptors

Receptor	Minimum headroom to 30mph speed limit	2012 baseline PM_{10} annual mean	PM_{10} annual mean with percentage increase of minimum headroom to 30 mph speed limit				
			20% ($\mu g.m^{-3}$)	40% ($\mu g.m^{-3}$)	60% ($\mu g.m^{-3}$)	80% ($\mu g.m^{-3}$)	100% ($\mu g.m^{-3}$)
30 West High St (1st floor)	17.5 mph	**20.8**	**20.3**	**20.0**	**19.9**	**19.8**	**19.7**
12 - 14 West High St (1st floor)	17.5 mph	**21.5**	**21.1**	**20.8**	**20.7**	**20.6**	**20.5**
1 to 5 East High St (1st floor)	8.1 mph	**22.7**	**22.5**	**22.3**	**22.1**	**22.0**	**21.9**
41 to 39 East High St (ground floor)	8.1 mph	**20.8**	**20.7**	**20.6**	**20.5**	**20.4**	**20.3**

7.2 Test Option 2 – Reduce traffic queue lengths during peak periods at the junction of West High Street and Comrie Street

Traffic can become slow moving and congested at certain locations in Crieff during peak times. Observations made during a traffic survey conducted in May 2013 indicated that westbound traffic appears to queue regularly throughout the day at the western end of West High Street (A85), with longer queues occurring during peak periods; this may be a result of vehicles waiting to turn right onto Comrie Street, while waiting for eastbound traffic to pass.

Analysis of the queue survey at this location indicated that there were westbound queues occurring as follows:

- 10m queues occurring approximately 3 - 5 times per hour during normal hours
- 20 - 30m during peak periods (8-9am; 12 - 1pm; 4pm - 5pm)

Eastbound traffic on Comrie Street heading east along the A85 also appears to experience congestion at this junction. Analysis of the queue survey data indicated:

- 10 m queues regularly throughout day at lights
- Up to 40 m from 8am - 9am
- 20 - 30m between 12pm - 1pm
- 20m from 1pm - 2pm
- Up to 40m queues from 4pm to 5 pm

If the priority is changed here so that traffic had right of way along this route, it may cut down on vehicle queuing within the section of West High St Street where canyon effects are limiting pollutant dispersion; and on the section of Comrie Street where traffic is approach the junction from the west.

This scenario assumes that changing the traffic flow priority at this junction could decrease both eastbound and westbound vehicle queuing time by up to 75%. A comparison of the predicted annual mean NO_2 and PM_{10} concentration at the 30 West High St (1st floor) and 9 Comrie Street diffusion tube location, which are the specified receptors closest to where the queuing occurs on West High Street and Comrie Street, are presented for NO_2 in Table 18 and PM_{10} in Table 19.

The results indicate that a reduction of up to 3.5 µg.m^{-3} in annual mean NO_2 concentrations at West High Street may be achievable if queue times can be reduced at this location; this could help achieve compliance with the 40 µg.m^{-3} objective at this location. A reduction of 1.4 µg.m^{-3} in annual mean PM_{10} concentrations is predicted; this is not sufficient to achieve compliance with the 18 µg.m^{-3} Scottish objective at this location using this measure alone.

Table 18: Scenario 2 – Reduce queuing times at junction of West High St/Comrie St - Predicted NO_2 annual mean concentrations at relevant receptors

Receptor	2012 baseline NO_2 annual mean	NO_2 annual mean with 75% reduction in queuing times
30 West High St (1st floor)	**40.5**	37
9 Comrie Street diffusion tube	23.1	17

Table 19: Scenario 2 – Reduce queuing times at junction of West High St/Comrie St - Predicted PM_{10} annual mean concentrations at relevant receptors

Receptor	2012 baseline NO_2 annual mean	NO_2 annual mean with 75% reduction in queuing times
30 West High St (1st floor)	**20.8**	**19.4**
9 Comrie Street diffusion tube	17	14.9

7.3 Test Option 3 - Decrease in the number of HGV traffic passing through the AQMA

The traffic data used for assessment indicates that HGVs account for approximately 5% of the average daily traffic flow through the town. This scenario models the effect of reducing the number of HGV traffic passing through Crieff in increments from 5% down to 2%.

There may also be some potential for freight operators to use more modern/lower emitting vehicles on this route; we have also therefore included a lower emission scenario whereby HGVs passing through the AQMA are restricted to Euro 5 or Euro 6 classification. Emissions of NOx and PM_{10} from vehicles are regulated under various European Directives which specify emission standards for different vehicle types. The emission standards become increasingly stringent for newer vehicles over time. Vehicles meeting specific emissions regulations are classified according to a "Euro" class with the most recent vehicles being Euro 6.

A comparison of predicted annual mean NO_2 and PM_{10} concentrations for each different HGV scenario are presented in Table 20 and Table 21. A reduction in HGV to 2% of the fleet leads to predicted annual mean NO_2 concentration below the 40 $\mu g.m^{-3}$ objective at all of the worst case receptor locations.

Restricting HGV traffic to Euro 5 and 6 vehicles achieves compliance with the NO_2 annual mean objective at all of the worst case receptors except for at 1- 5 East High Street.

For PM_{10}, reducing HGV numbers does provide a benefit by reducing annual mean concentration at all receptors by up to 0.9 $\mu g.m^{-3}$; it is not however sufficient to achieve the 18 $\mu g.m^{-3}$ annual mean objective at any of the worst case receptor locations. Restricting HGV traffic to Euro 5 and 6 classification only has no benefit at all in terms of reducing annual mean PM_{10} concentrations.

Table 20: Scenario 1 – Increase average speed through AQMA – Predicted NO_2 annual mean concentrations at worst case receptors

Receptor	Predicted NO_2 annual mean concentration ($\mu g.m^{-3}$)				
	2012 baseline (5% HGV)	4% HGV	3% HGV	2% HGV	5% HGV - Euro 5 & 6 only
30 West High St (1st floor)	**40.5**	38.2	36.0	33.7	37.5
12 - 14 West High St (1st floor)	**42.3**	**40.1**	37.9	35.6	39.0
1 to 5 East High St (1st floor)	**45.8**	**43.3**	**40.9**	38.4	**42.1**
41 to 39 East High St (ground floor)	38.7	36.6	34.6	32.6	35.3

Table 21: Scenario 1 – Increase average speed through AQMA – Predicted PM_{10} annual mean concentrations at worst case receptors

Receptor	Predicted PM_{10} annual mean concentration ($\mu g.m^{-3}$)				
	2012 baseline (5% HGV)	4% HGV	3% HGV	2% HGV	5% HGV - Euro 5 & 6 only
30 West High St (1st floor)	**20.8**	**20.5**	**20.2**	**20.0**	**20.8**
12 - 14 West High St (1st floor)	**21.5**	**21.2**	**20.9**	**20.6**	**21.6**
1 to 5 East High St (1st floor)	**22.7**	**22.4**	**22.1**	**21.8**	**22.8**
41 to 39 East High St (ground floor)	**20.8**	**20.6**	**20.3**	**20.1**	**20.9**

8 Summary and Conclusion

In this Further Assessment, concentrations of NO_2 and PM_{10} have been assessed in the Crieff AQMA in Perthshire. A combination of available monitoring data and atmospheric dispersion modelling using ADMS-Roads were used to conduct the study. The study used recently acquired traffic and meteorological data for Crieff to assess a baseline year of 2012.

The study has confirmed the findings of the previous Detailed Assessment, namely that there are exceedences of the annual mean NO_2 objective and annual mean PM_{10} objective where relevant exposure exists. The contour plots showing the modelled spatial variation in pollutant concentrations prepared for this study indicate that the current AQMA boundaries include all relevant sources and do not require revocation or amendments at this time.

Within the Crieff AQMA, the dispersion modelling results indicate that up to 70 residential properties within the AQMA were exposed to exceedences of the annual mean NO_2 and PM_{10} objectives during 2012, , equating to an exposed population of approximately 153 people.

It is estimated that emission reductions of Road NOx in the Crieff AQMA of up to 22% are required in order to achieve compliance with the annual mean NO_2 objective at all locations of relevant exposure. For compliance with the annual mean PM_{10} objective, it is estimated that a reduction in the Road contribution of PM_{10} of up to 46% is required.

The source apportionment exercise indicates that the proportion of emissions from queuing traffic is higher at the western end of West High Street than at other locations. Traffic surveys indicate that traffic appears to queue regularly throughout the day at this location with longer queues occurring during peak periods; this may be when vehicles are waiting to turn right onto Comrie Street.

The source apportionment also indicated that the highest proportion of NOx emissions at all receptors is from HGV's and Cars; and that NOx and PM10 emissions from buses are relatively low when compared to other vehicle types.

Three mitigation scenarios were modelled as follows:

1. Reduce emissions by increasing the average vehicle speed through sections of the AQMA; achieved by implementing parking improvements.

2. Change priorities at the junction of West Street and Comrie Street where traffic turning right has been observed to queue while waiting for eastbound traffic to pass.

3. A decrease in the number of HGV traffic passing through the AQMA

The modelling results for the three mitigation scenarios indicated that each option will provide a reduction in both NOx and PM_{10} emissions. The predicted reduction in NO_2 concentrations were much greater than the predicted reduction in PM_{10} concentrations for all scenarios tested.

The modelling results indicate that compliance with the NO_2 annual mean objective may be achievable by implementing the measures modelled in this assessment. It is likely that a combination of measures will be required to reduce annual mean PM_{10} concentrations sufficiently to be compliant with the Scottish objective.

The monitoring and dispersion modelling carried out to support this Further Assessment indicates that exceedences of the NO_2 and PM_{10} annual mean objectives are still occurring within the Crieff AQMA. The boundaries of the AQMAs are therefore still appropriate and do not require to be revoked or amended at this time.

Perth & Kinross Council should continue with development of an Air Quality Action Plan for the Crieff AQMA and continue to monitor concentrations of PM_{10} and NO_2 in the area.

9 Acknowledgements

Ricardo-AEA gratefully acknowledges the support received from Kirsty Steven, Lynne Reid and Martin Petrie of Perth & Kinross Council when completing this assessment.

Appendices

Appendix 1: Traffic data

Table A1.1 summarises the Annual Average Daily Flows (AADF) of traffic and fleet compositions used within the model for each road link.

Traffic data for the assessment was available from both local surveys commissioned by Perth & Kinross Council; and from the freely available Transport Scotland/DfT national traffic count datasets. Annual average daily traffic (AADT) flows and vehicle fleet split data for the A85 was accessed from the national traffic datasets.

The local traffic surveys conducted in May 2013 provided detailed information on various different elements. The data used for the Further Assessment included observed vehicle queue lengths, typical stop times at the pedestrian crossings, and journey times through different sections of the town which allowed estimates of average speeds to be calculated.

Table A1.1: Crieff – Perth Road - Annual Average Daily Flows

Street	%Cars	%LGV	%HGV	%Bus	%2WM	AADF 2012
A85 Perth Road	78.2	14.9	5.1	0.8	0.9	5931
A85 Comrie Street	75.1	14.5	4.6	1.5	4.4	3305

LGV – Light Goods Vehicles

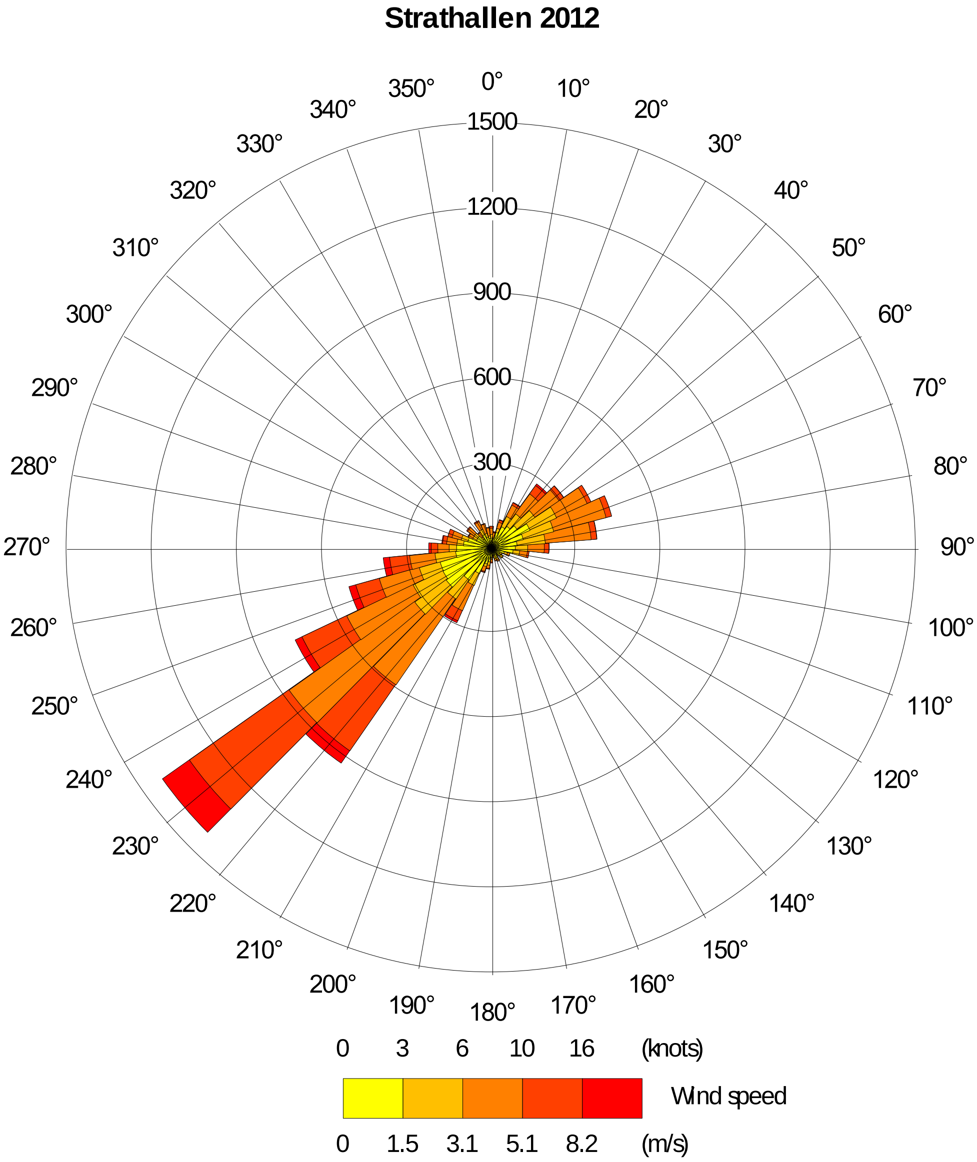
HGV – Heavy Goods Vehicles (Articulate and Rigid)

2WM – Motorcycles

Appendix 2 – Meteorological dataset

The wind rose for the Strathallen Airfield meteorological measurement site is presented in Figure A2.1.

Figure A2.1: Meteorological dataset wind rose



Appendix 3 – Model Verification

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. This helps to identify how the model is performing at the various monitoring locations. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. LAQM.TG(09) recommends making the adjustment to the road contribution only and not the background concentration these are combined with.

NO_2

The approach outlined in Example 2 of LAQM.TG(09) has been used in this case.

As stated in Section **Error! Reference source not found.** above, the model was verified using annual mean NO_2 measurements from the automatic PM_{10} and NO_2 analysers; and the various NO_2 diffusion tube sites in Crieff. It is appropriate to verify the ADMS Roads model in terms of primary pollutant emissions of nitrogen oxides ($NO_x = NO + NO_2$). The model has been run to predict annual mean Road NO_x concentrations during the 2012 calendar year at the diffusion tube sites. The model output of Road NO_x (the total NO_x originating from road traffic) has been compared with the measured Road NO_x, where the measured Road NO_x contribution is calculated as the difference between the total NO_x and the background NO_x value. Total measured NO_x for each diffusion tube was calculated from the measured NO_2 concentration using the latest version of the Defra NO_x/NO_2 calculator.

The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution. Subsequently, some small refinements were made to the model input to improve the overall model performance.

The gradient of the best fit line for the modelled Road NOx contribution vs. measured Road NOx contribution was then determined using linear regression and used as the adjustment factor. This factor was then applied to the modelled Road NOx concentration for each modelled point to provide adjusted modelled Road NOx concentrations. A linear regression plot comparing modelled and monitored Road NOx concentrations before and after adjustment is presented in Figure A3.1.

A primary adjustment factor (PAdj) of 2.4359 based on model verification using 2012 monitoring results was applied to all modelled Road NOx data prior to calculating an NO_2 annual mean. A plot comparing modelled and monitored NO_2 concentrations before and after adjustment is presented in Figure A3.2.

PM_{10}

In the case of PM_{10}, as there is only a single monitoring location a simple arithmetic correction was derived. The model divergence for Road PM_{10} at this location was a factor of **4.8631**. This value was applied to all modelled Road PM_{10} predictions before the annual mean background concentration as added. There is considerable uncertainty in the PM_{10} model predictions at locations away from the monitoring site.

Figure A3.1 Comparison of modelled Road NO_x Vs Measured Road NO_x

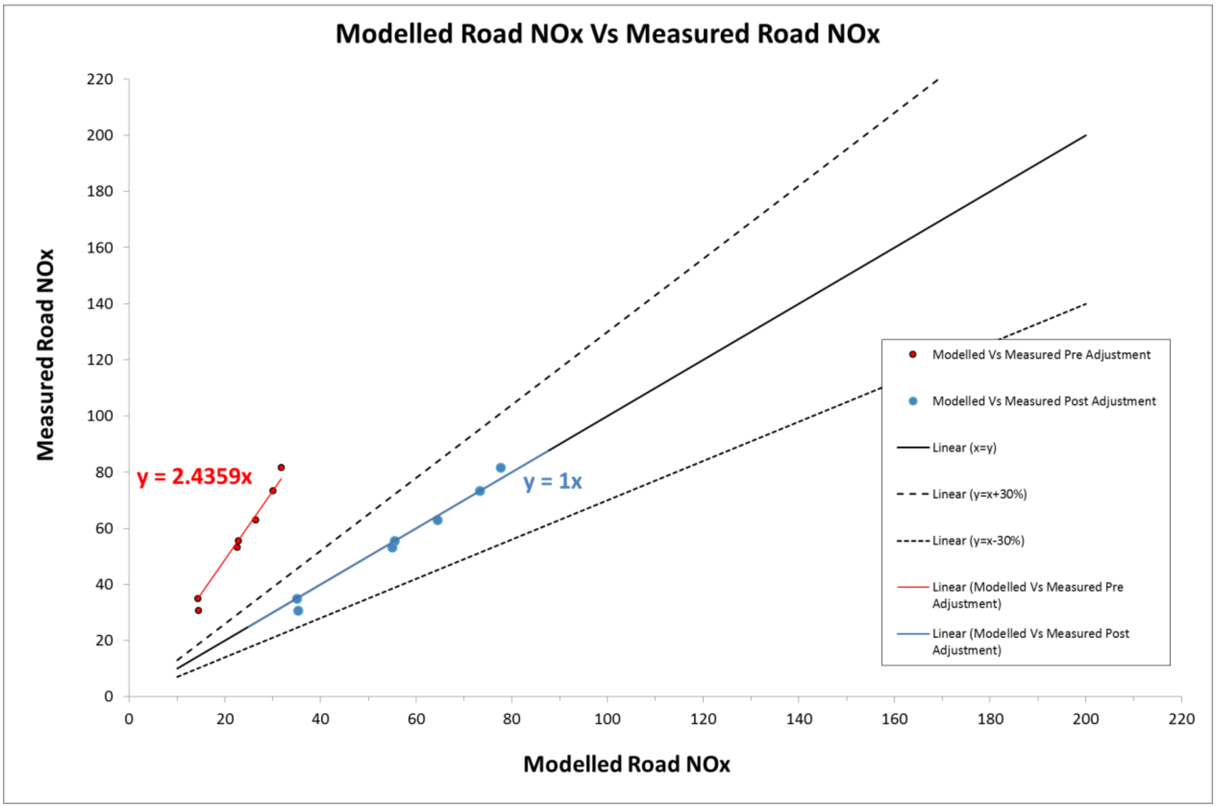
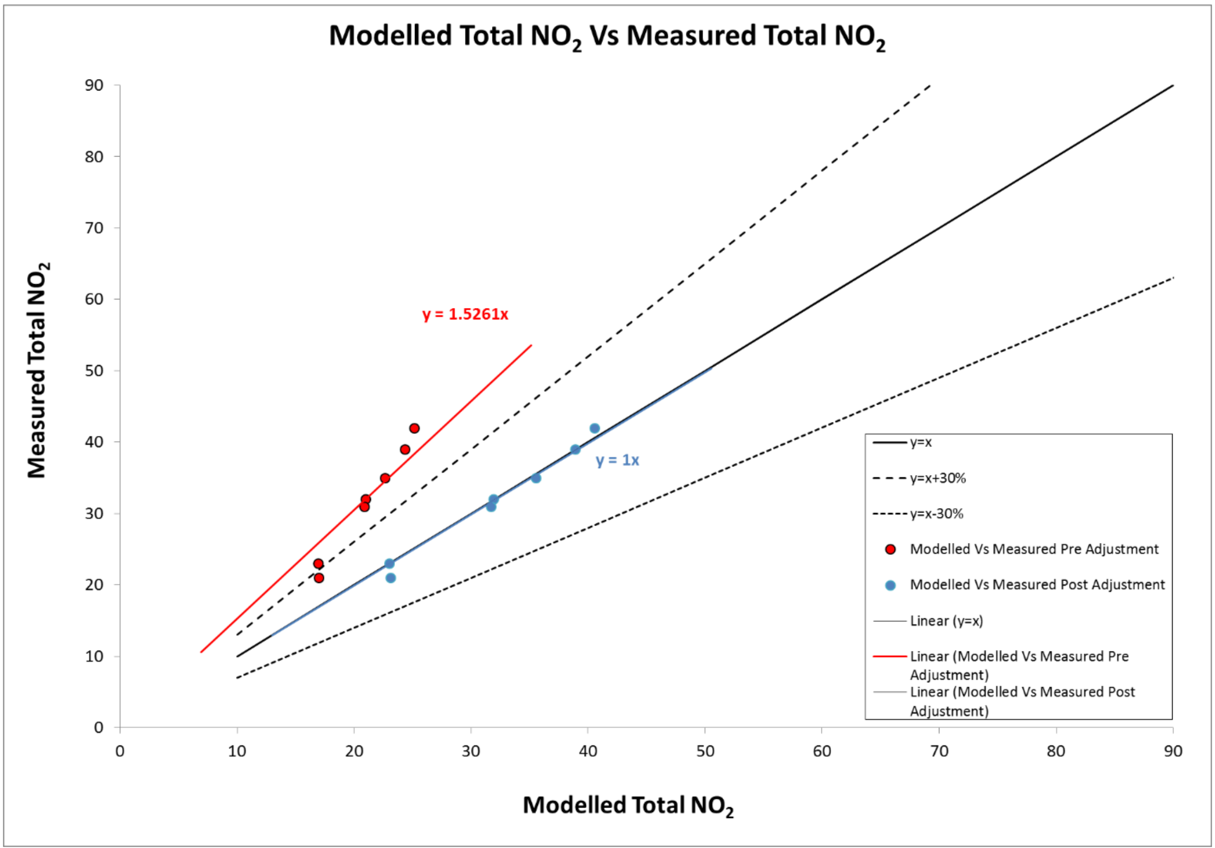


Figure A3.2 Comparison of modelled vs. monitored NO_2 annual mean 2013



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